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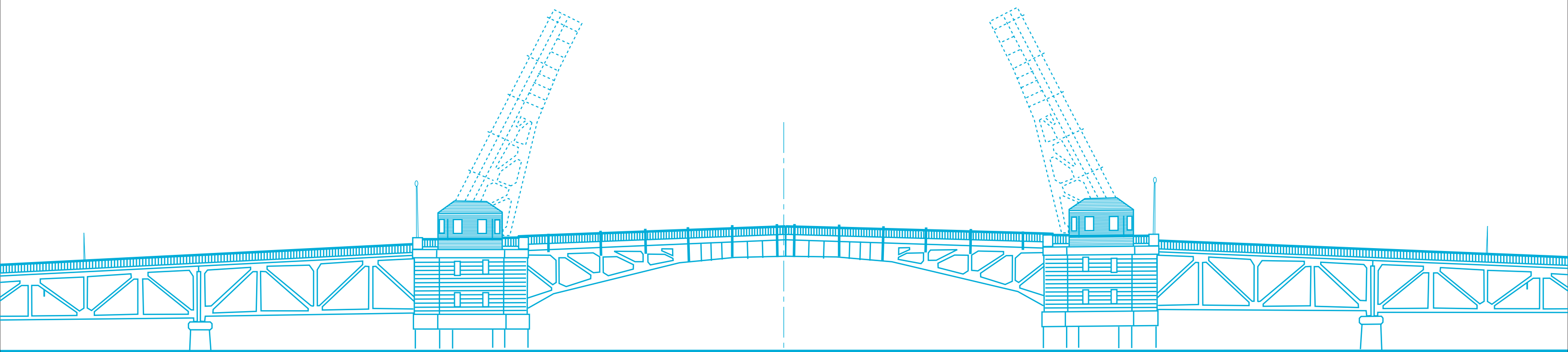

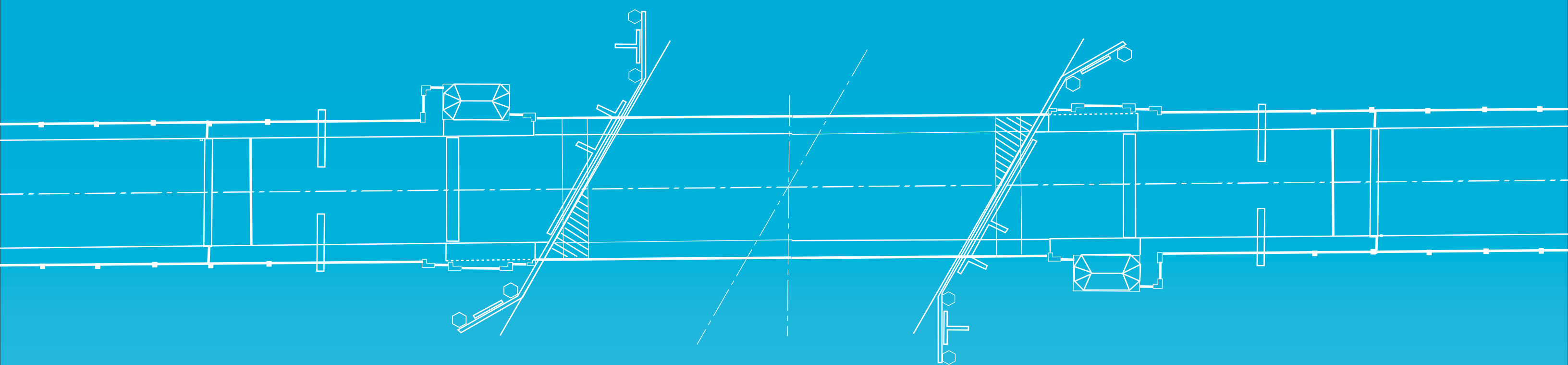

South Park Bridge

Rehabilitation Feasibility Study

Technical Memorandum

prepared for:
King County Department of Transportation

prepared by:
Parsons Brinckerhoff, Inc

May 2003

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SOUTH PARK BRIDGE PROJECT

Rehabilitation Feasibility Study

Technical Memorandum

Prepared for the
King County
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EXECUTIVE SUMMARY

The South Park Bridge Rehabilitation Feasibility Study is part of a conceptual structural engineering investigation to support the preparation of the South Park Bridge Environmental Impact Statement (EIS). The objective of the study is to investigate the feasibility of maintaining the existing transportation link across the Duwamish River. The rehabilitation alternative was selected as an EIS alternative and strongly favored by the South Park Community. It allows for maximum preservation of historic values and minimal changes to the South Park neighborhood. In this report, two conceptual design options are evaluated and a recommendation is made that defines the Rehabilitation Alternative that will be analyzed in the EIS.

Study Objective

Rehabilitating the existing bridge would be a viable solution if after rehabilitation, the bridge would: 1) meet current transportation design standards, 2) comply with current AASHTO seismic design standards, 3) have an extended long-term service life, and 4) maintain as many existing structural features as possible. Here, the term rehabilitation encompasses both rehabilitation (upgrade to meet current transportation design standards) and/or retrofitting (seismic upgrade). For cost estimate and comparison purposes, the targeted long-term service life of the rehabilitated structure is targeted to be 70 years [Ref. 3], which is generally considered the minimum for a new bridge.

Previous studies have tried to address either interim rehabilitative measures to alleviate distress to the bridge, or seismic vulnerability and possible rehabilitation solutions, but none of these studies were scoped to combine the two (i.e. to minimize seismic risk AND mitigate operational issues through rehabilitation). Most previous studies have acknowledged that the bridge is nearing the end of its useful design life and have assumed that the existing bridge would be replaced within the next ten to twenty years. Because of this assumption, the solutions presented in previous studies were "band-aids" that generally did not mitigate seismic hazards or operations and maintenance issues to a standard commensurate to a structural design life of approximately 70 years [Ref. 3].

Options Evaluated

In order to rehabilitate the existing bridge to the end of its current useful life and also extend its life, mitigate seismic safety, as well as address operations and maintenance issues arising from its deteriorated condition, it was necessary to investigate additional measures beyond those addressed in previous reports. For this reason, two distinct approaches to rehabilitate the existing South Park Bridge were identified and evaluated:

- Rehabilitation Option 1: Preserve and reinforce most of the original substructures without removing the bascule leaves during construction to minimize interruption to vehicular, bicycle and pedestrian traffic.
- Rehabilitation Option 2: Replace the bascule piers and foundations, concrete approach structures, and steel truss approach piers. The bascule leaves and approach trusses would be temporarily removed, refurbished and reinstalled during the construction.

This feasibility study comprehensively examines these options to rehabilitate the existing South Park Bridge. Determinations regarding the condition of the existing bridge were made based on numerous past studies as well as examinations conducted as part of this study. Based on this information, criteria and approaches to rehabilitate the bridge were developed to guide the specific repair and reconstruction work for the two options to rehabilitate the bridge. In particular, efforts to rehabilitate the bridge examined each of the major structural elements of the bridge including: 1) bascule foundations, piers, and leaves; 2) steel trusses; 3) concrete approaches; 4) retaining wall; and 5) mechanical and electrical systems. The analysis also considered constructibility, impacts on the community, and preservation of the historic character of the bridge structure. In addition, conceptual cost estimates were developed to compare the two options.

Comparison of Options

This section compares the advantages and disadvantages of the two rehabilitation options and proposes a final recommendation for the proposed rehabilitation of the South Park Bridge.

Rehabilitation Option 1

(rehabilitate most of the existing substructure by adding supplemental structure)

Advantages

The existing bridge could be open to vehicular traffic during part of the substructure construction period, avoiding complete closure during the entire construction period (as in Option 2).

Disadvantages

- The additional substructure required to strengthen the approach structures would add more columns and footings in the river.
- The existing structure's historical appearance would be significantly altered by the addition of structural members used to strengthen the steel truss approach piers and bascule piers.
- Rehabilitation would require the use of difficult and higher-risk construction methods (i.e., drilling through existing pile caps, and the potential differential settlement of the existing footing during construction).
- The uncertain existing condition of the substructure concrete and footings would result in a less predictable remaining service life.

Rehabilitation Option 2

(replace bascule piers, approach piers, and concrete approaches and rehabilitate steel trusses)

Advantages

- The reconstructed bascule piers and steel truss approach piers would be nearly the same size as the existing structure footings in the river.
- The existing bridge's historical appearance would be mostly preserved.
- The remaining service life would be relatively predictable compared to Option 1.

Disadvantages

- Significant construction impacts on vehicle, bicycle, and pedestrian traffic and the South Park community because the bridge would be closed for rehabilitation for up to three years.

These comparisons between the two rehabilitation options are summarized in the table below. A plus sign (+) indicates that one option is relatively better than the other, and a negative sign (-) indicates that it is relatively worse. The estimated costs to construct these two options are similar. It is important to keep in mind that both rehabilitation options would provide only three traffic lanes, compared to four traffic lanes that could be incorporated into other possible structural solutions.

Comparison of Rehabilitation Options

Comparison Items	Option 1	Option 2
Construction Impact on Land Traffic	+	-
Impact on Water Way Navigation Clearance	-	+
Impact on Historical Appearance	-	+
Remaining Service Life of the Structure	-	+
Construction Cost	Same	Same

Recommendation

The previous comparisons indicate that except for the disadvantage of having a longer construction impact on land traffic, Option 2 compares equally or more favorably than Option 1 in all comparison categories. Option 2 would provide a wider waterway clearance for navigation and would have a more predictable remaining service life. From the historical preservation point of view, Option 2would provide an opportunity to rebuild the structure and preserve the same appearance as the existing bridge, but Option 1 would require significantly altering the existing appearance. Although Option 1 would “preserve” the existing bascule piers and footings, it is important to consider the unfavorable comparisons listed above. Considering that Option 1 would significantly change the bridge’s existing appearance, the questions to consider is whether it would be worth paying the estimated high cost to preserve the deteriorated concrete. In our opinion, Option 1 is not a good choice unless it is absolutely necessary to preserve the deteriorated substructure concrete material at the existing location.

Based on this conclusion, PB recommends Rehabilitation Option 2 as the proposed Rehabilitation Alternative for environmental review in the South Park Bridge Project EIS. Option 2 should also be further evaluated and compared with the three other structural alternatives being considered for this bridge, including: (1) replacement with a new bascule bridge on a new alignment, (2) replacement with a new mid-level fixed bridge on a new alignment, and (3) replacement with a new high-level fixed bridge on a new alignment.

1. INTRODUCTION

This feasibility study describes the conceptual structural design effort and issues investigated for rehabilitation and/or retrofit of the existing structure. The following sections provide background information about the existing South Park Bridge and the goals for rehabilitation of the bridge.

Background

The South Park Bridge (formerly called the 16th Avenue South Bridge) is a double-leaf bascule bridge built in 1931. Because it is the only operational example of a Scherzer rolling lift bascule bridge in the state of Washington, the bridge is listed on the National Historic Register [Refs. 22, 23]. See Photo 1.

The current South Park Bridge is nearing the end of its useful life [Refs. 3, 11, 49] and has exhibited numerous operational problems in recent years, related to the opening and closing of the bridge to navigation traffic on the Duwamish River and the deteriorated condition of the bascule piers. In 2002, it was given a Washington State Bridge Inventory System (WSBIS) sufficiency rating of 6 out of a possible 100, and labeled "structurally deficient" by FHWA standards [Ref. 19]. It also sustained significant damage in February 2001 during the Nisqually Earthquake. The earthquake damage required several nighttime closures to mitigate structural problems to the main spans and bridge approaches and to restore operations. King County has commissioned the preparation of conceptual engineering and an EIS to evaluate potential alternatives for rehabilitating or replacing the existing bridge.

In support of this effort, five alternatives were identified through scoping, alternative screening, and outreach with stakeholders: (1) Rehabilitation of the existing structure; (2) Replacement with a new bascule bridge on a new alignment; (3) Replacement with a new mid-level fixed bridge on a new alignment; (4) replacement with a new high-level fixed bridge on a new alignment; and (5) no action.

Photo 1: Current View of the South Park Bridge

The following two engineering terms are used in this report: *Retrofit* is specifically used to describe seismic upgrade related construction activities, and *rehabilitation* is used to describe construction activities that upgrade an existing bridge to meet current design standards for the existing and future service load requirements. For simplicity, the term rehabilitation is also used in this document as a general term for both rehabilitation and retrofit.

The Rehabilitation Alternative's Goal

The project's Purpose and Need Statement reads as follows from the *South Park Bridge Project Summary Technical Report: Alternatives Development and Screening* (Parsons Brinckerhoff, Inc., September 6, 2002) [Ref. 12]:

> *Purpose of Proposed Action: The purpose of the proposed action is to find the most feasible long-term solution to address the deteriorated condition and increasing seismic vulnerability of the South Park Bridge, while maintaining a vital transportation linkage for cars, trucks, buses, bicyclists and pedestrians across the Duwamish River.*
>
> *Need for the Proposed Action: In spite of substantial ongoing maintenance and repairs, the South Park Bridge has suffered significant deterioration over the past 70 years. Existing problems with the bridge worsened significantly following the Nisqually Earthquake in February 2001 and the bridge remains vulnerable to future seismic events.*

Based on the above statement and from the structural study aspect, the rehabilitation goals are to provide a structure that would 1) be able to maintain a vital transportation link across the Duwamish River over the long term, without major repairing or re-construction; and 2) meet current AASHTO seismic design standards.

2. EXISTING STRUCTURE CONDITION

The first phase of this study effort is to assess the current condition of the South Park Bridge. To facilitate the reader's understanding of this assessment, the first section of this chapter describes the several structural components of the existing bridge. Following is a review of condition findings from previous studies. These studies are included in the list of references at the end of this document. The findings of recent visual inspections of the bridge are also included in this assessment of the current structural condition of the bridge. A number of photos are also included to document these findings.

Description of the South Park Bridge

Figure 1 on the following page provides a schematic of the bridge and identifies each of its major structural components, which are discussed in more detail later. The following are brief descriptions of the South Park Bridge's major structural components:

Bascule Pier Foundations – The bascule pier foundations include the concrete footing, the piling embedded in the footing, and the concrete tremie seal.

Bascule Piers – The bascule piers are thick reinforced concrete walls that support the rolling girder tracks, the bascule leaves, and one end of the steel truss approaches. The walls surround a large, deep counterweight pit. When the bridge rolls back in the open position, the counterweight sinks into the pit in the center of the pier. The bascule piers also contain the operator's house, where the controls that open and close the bridge are located.

Bascule Leaves – The bascule leaves form the movable span portion of the bridge. This includes the steel truss superstructure (which supports the deck and sidewalks), the steel rolling girders (which are part of the lift mechanism), and the counterweights. The existing bridge deck is an open-grated steel deck system. The motor rooms that drive the lift mechanism are also contained on each bascule leaf near the counterweights.

Steel Approach Truss Foundations – The pile cap and piling comprising the foundation support the steel approach spans.

Steel Approach Truss Piers – Steel approach truss piers support the truss and deck. The existing piers are lightly reinforced concrete.

Steel Approach Trusses – Steel approach trusses support the bridge approach deck.

Concrete Approach Foundations – Foundations for each concrete approach pier column consist of a square footing and four piles.

Concrete Approach Piers – Concrete piers support the concrete slabs. Each pier is comprised of three columns. Typical concrete approach pier columns are 22 inches square and lightly reinforced.

Concrete Approach Slabs –Six spans of concrete slabs supported on approach retaining walls form the concrete approach deck at each end of the bridge.

Abutments – Reinforced concrete structures that support the ends of the first (lowest) span of each concrete approach.

Retaining Walls – Reinforced concrete retaining walls hold retained fill between the abutment and the point at which the roadway returns to grade.

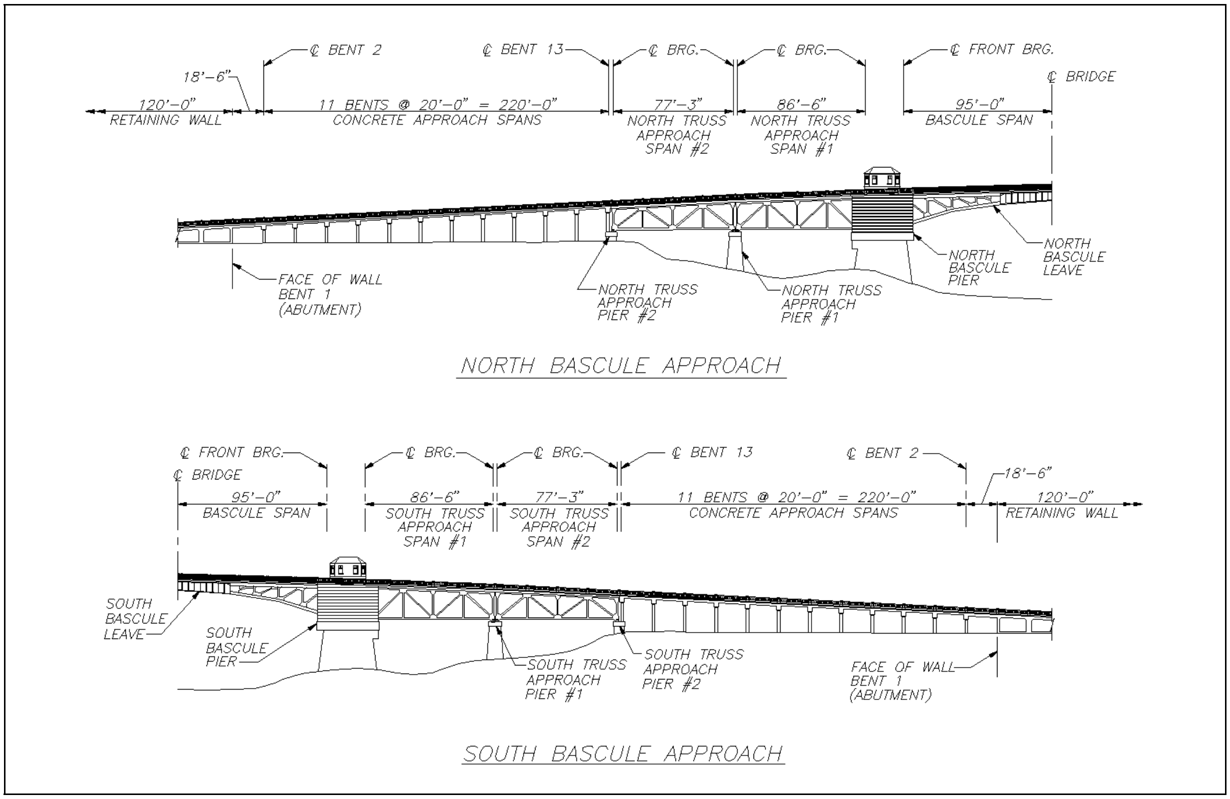

Figure 1: Existing South Park Bridge Plan

Existing Condition of the South Park Bridge

This section includes brief summaries of the existing structure's major problem. These summaries are based on findings from previous reports and new field observations.

Overall Condition

Recent WSBIS bridge inspection reports were reviewed. Under NBIS/WSBIS guidelines, bridge inspection reported the South Park Bridge had a Sufficiency Rating in 2002 of 6 out of 100 (100 is the best score). This rating placed the bridge in a "structurally deficient" category [Ref. 19].

Various bridge components were also rated. WSBIS/NBIS condition ratings for bridge components range from 0 to 8. An 8 rating is considered "excellent condition," 5 is considered "fair," and anything 4 or lower is considered "poor" [Refs. 27, 42]. Each component rating is discussed in the following paragraphs.

Bascule Pier Foundations

Insufficient Existing Pile Capacity [Refs. 4, 13, 20]
Original pile driving records indicate that the timber piles under the north bascule pier were not driven to refusal in the glacial till. The pilings were driven short of this layer by approximately 10 to 20 feet. The existing wood piles supporting the north and south bascule pier foundations are reported to have been originally designed for an allowable load of about 22 tons each. Based on the results of pullout tests at the south pier, it is estimated that the design load of the piles is increased from 22 to 30 tons. Based on the

recorded final driving resistances and the results of pullout tests, it is the geotechnical consultant's opinion that the piles driven at the south bascule pier would have an ultimate compression capacity of 50 tons and a tension capacity of 45 tons. For the north bascule pier, the estimated allowable pile capacities would range from about 6 to 12 tons, which are much less than the required design loads of 22 to 30 tons.

Over time, differential settlement between the two bascule piers has contributed to bascule leaf operation problems, including leaf misalignment.

<u>Liquefiable Soil [Refs. 2, 4, 13, 46]</u>
For a 475-year return period of seismic ground motions and based on the available subsurface data, the estimated potentially liquefiable deposits would extend to approximately 35 feet deep within and south of the Duwamish River Waterway. North of the waterway, these deposits would be extended to approximately 50 feet deep. Liquefiable soils in the Duwamish River Valley may be subjected to lateral displacement (lateral spreading) varying up to approximately 8 to 10 feet. Vertical settlement for these areas may be as much as 2 feet.

Bascule Piers

Condition reports and studies that have been collected over the past 20 years outline the poor and deteriorating condition of bascule piers.

<u>Deteriorating Concrete and Rusting Reinforcement [Refs. 8, 18, 19, 27]</u>
In 2000, the rating from the *WSBIS Bridge Inspection Report* [Ref 19] for the substructure was 4 out of 8 (8 indicates excellent condition) [Ref. 27]. A 4 rating corresponds to poor condition. In 2002, the rating for the substructure moved down to a 3 rating, which is considered in "serious condition" per NBIS, which corresponds to the following statement [Ref. 27]: "Loss of section, deterioration, spalling or scour have seriously affected primary structural components. Local failures are possible." See Photos 2 through 5, 7, and 8.

The overall condition of the submerged section of the two bascule piers ranges from fair to poor. Evidence of significant deterioration in the form of cracking, spalling, and efflorescence is found in both piers. The north bascule pier has sustained the most significant deterioration of all six substructure piers, which support the bridge across the waterway [Ref. 8]. The counterweight pits on both bascule piers have an inflow-outflow opening to allow high tide waters to flow into and out of the pier. This wet-dry cycle of tides further aggravates any spalling due to rebar corrosion and chloride attack of the pier walls. See Photo 6. Cracking in the bascule piers is further exacerbated by the rolling action of the leaves and changes in load pressure on the foundation [Ref. 18]. See Photo 9.

<u>Unpredictable Concrete Strength</u>
A direct comparison of two immediately adjacent concrete cores (one taken during the 1986 inspection and one taken during the 1994 investigation) showed the ultimate compressive strength of the concrete to be 4,500 pounds per square inch (psi) and 3,250 psi, respectively. This represents a reduction of 1,250 psi, or a loss of 28% in the concrete's compressive strength [Ref. 8]. In 1997, concrete core samples were again taken and compared to previous results from the 1994 and 1986 core samples [Ref. 18]. The results of the 1997 compression testing show a large variance, with no apparent trend in continuing loss of strength as might have been inferred from the 1994 data. The variance in compressive strength is so great that the averages have limited utility from an engineering perspective.

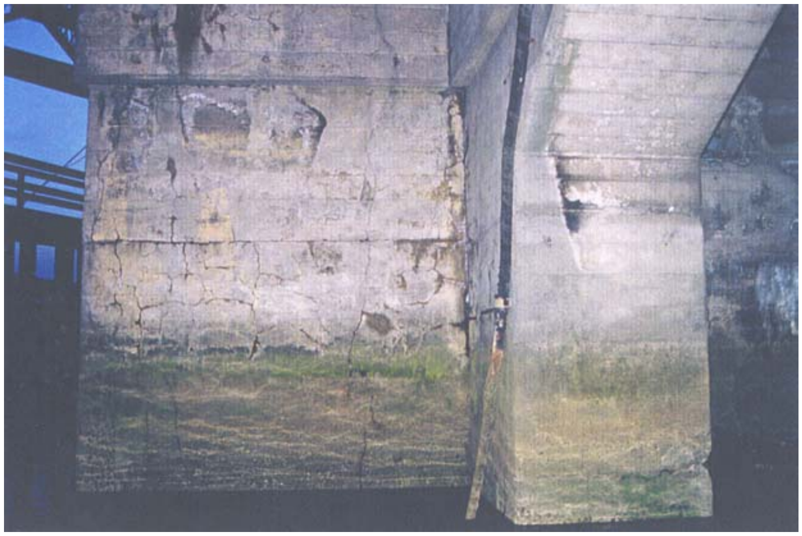

Photo 2: North Bascule Pier (East Face)
Note the numerous hairline cracks that extend across the face of the bridge in the splash zone.
(from *Echelon Engineering Inspection Report*, Ref. 18)

Photo 3: North Bascule Pier (South Face)
Note the extensive hairline cracking (map cracking) with efflorescence.
(from *Echelon Engineering Inspection Report*, Ref. 18)

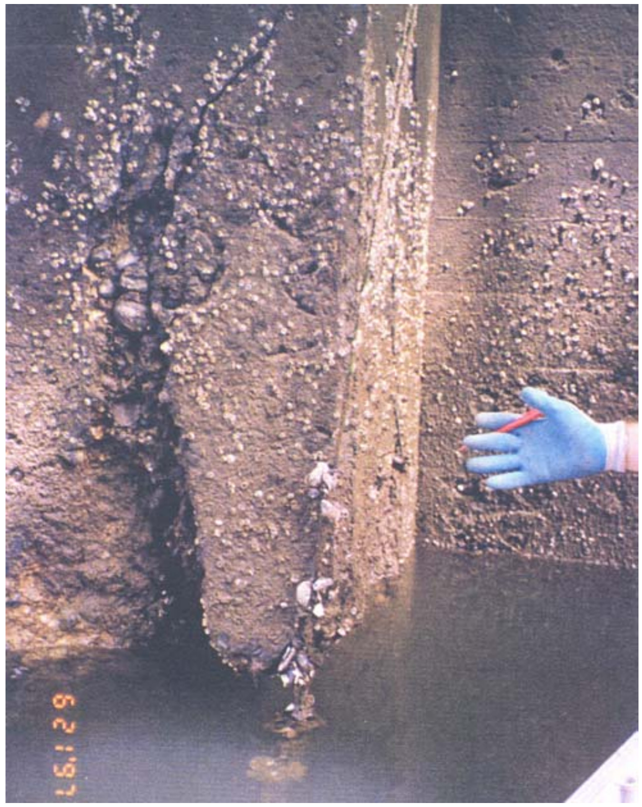

Photo 4: North Bascule Pier (South Face Detail)
Note the large corner spall that exhibits an extensive loss of concrete immediately below the water.
(from *Echelon Engineering Inspection Report*, Ref. 18)

Photo 5: North Bascule Pier (West Face)
Note the extensive hairline cracking (map cracking) and efflorescence.
(from *Echelon Engineering Inspection Report*, Ref. 18)

Photo 6: North Bascule Pier (North Face)
Spalling of the inlet/outlet locations. Note the exposed rebar at the left opening and the sedimentation of the right opening.
(from *Echelon Engineering Inspection Report*, Ref. 18)

Photo 7: South Bascule Pier (North Face)
Note the vertical crack at far right.
(from *Echelon Engineering Inspection Report*, Ref. 18)

Photo 8: South Bascule Pier (South Face Details)
Note the corner spall, vertical and horizontal cracks along the face.
(from *Echelon Engineering Inspection Report*, Ref. 18)

Photo 9: North Bascule Pier (West Wall)
Note the multiple and substantial cracks in the bascule pier wall.

Crack Development from the Tiltmeter Monitoring Report

Tiltmeter monitoring revealed that the transverse movement of the north and south piers is highly erratic. The 2002 monitoring report indicated that the piers are severely cracked, the bascule pier walls are moving away from one another and not acting as a solid unit under normal operating loads, and the February 28, 2001 earthquake had an adverse effect on the existing cracks (as evidenced from the increasing rate of tilt in the transverse direction after the earthquake). The report also predicted that as the structure ages, this cracking would increase due to unequal cyclic movement and lead to further deterioration [Ref. 20].

Chloride Induced Corrosion or Chemical Deterioration

Inspections conducted by Echelon Engineering, Inc. [Refs. 8, 18] showed no evidence of concrete deterioration due to sulfate attack. However, high levels of chloride ions were found in the samples. Echelon Engineering suggested the possibility of chloride-induced corrosion as a potentially significant contributor to the deteriorative process affecting the bascule piers [Refs. 8, 18].

Han-Padron Associates had a different opinion after an underwater inspection conducted on March 22, 2001. Han-Padron sent a letter to WSDOT that stated: “This type of deterioration is indicative of classic chemical deterioration of the concrete matrix, most likely sulfate attack, but also possibly attributable to alkali-silica reaction (ASR) or delayed ettringite formation (DEF). Further evidence [suggests] that the deterioration is not the result of reinforcing steel corrosion.” Han-Padron also suggested “the only definitive way to evaluate these interrelated variables is through petrographic analysis of concrete core samples.” [Refs. 47, 48]

Pier Reinforcement Does Not Meet Seismic Design Requirements

Previous studies have found that the reinforcement in the bascule pier walls does not meet current seismic design requirements [Ref. 45]. Additional reinforcement and post-tensioning were proposed as seismic rehabilitation schemes [Ref. 1].

Bascule Leaves

“Fair condition” (a rating of 5) was assessed for the superstructure and deck in the *WSBIS Bridge Inspection Report* [Ref. 19]. The WSBIS/NBIS system defines fair condition as “all primary structural elements are sound but may have minor section loss, cracking, spalling, or scour” [Refs. 27, 42]. However, this rating does not preclude the possibility that the condition of individual structural members may be deteriorated and require subsequent replacement. See Photo 10.

The bascule leaves do not have a complete lateral load path to bring the lateral earthquake load to the bearing from the deck level [Ref. 1].

Steel Approach Truss Foundations

The *Geotechnical Report* prepared by Shannon and Wilson in September 1991 indicated that subsurface soils above elevation -30 (City of Seattle datum) along both bridge approaches have a high potential to liquefy when subjected to the design ground motion (peak ground acceleration of 0.3g) [Ref. 2]. Piles for the steel approach truss foundations were driven to elevations ranging from –52 to –67 at Pier 1 for the north and south approaches, and elevations ranging from –33 to –41 at Pier 2 for the north and south approaches [Ref. 50]. The *Geotechnical Report for Conceptual Engineering – South Park Bridge Project* prepared by Shannon and Wilson in May 2003 [Ref. 28] indicated an increased soil liquefaction risk. For 475-year return-period ground motions and based on the available subsurface data, the estimated potentially liquefiable deposits would extend to approximately 35 feet (elevation –15) deep within and south of the Duwamish River Waterway. North of the waterway, these deposits would be extended to approximately 50 feet (elevation –35) deep. Liquefiable soils in the Duwamish River Valley may be subject to lateral displacement (lateral spreading) varying up to about 8 to 10 feet. Vertical settlement for these areas may also be as much as 2 feet [Ref. 46]. See Photo 11.

Photo 10: Bascule Leaves
Condition is fair, some corrosion discovered during bridge inspection [Ref. 19].

Photo 11: Steel Truss Approach, North Pier 2
Note the spalling of the two exposed footings.

Steel Approach Truss Piers

In 2002, the rating per the WSBIS report for the substructure was “3,” which is considered in “serious condition” [Ref. 19].

The deterioration of the steel truss approach piers has been confirmed visually, with testing, and in inspection reports by Echelon Engineering in 1997 [Ref. 18], Han-Padron Associates in 2001 [Refs. 16, 47, 48] and the PSI 2003 memo report [Ref. 49]. Cracking, spalling and chloride attack as well as alkali-silica reactions have been observed and recorded [Refs. 16,18, 47, 48]. See Photos 12 through 14. As-built drawings show no steel reinforcing in pier Number 1 columns or the outer columns of pier Number 2 for both approaches.

Photo 12: Steel Truss Approach, North Pier 1
Note the spalls and concrete repair patches on the corners of the columns.
(from *Echelon Engineering Inspection Report*, Ref. 18)

Photo 13: Steel Truss Approach, North Pier 1 East Column
Note the large spall on the southwest corner of
the column within the upper intertidal zone.
(from *Echelon Engineering Inspection Report*, Ref. 18)

Photo 14: Steel Truss Approach, North Pier 1 West Column
Note the large spall on the northwest corner of the column.
(from *Echelon Engineering Inspection Report*, Ref. 18)

Steel Approach Trusses

A "fair condition" rating of 5 was assessed for the superstructure and deck in the *WSBIS Bridge Inspection Report* [Ref. 19]. The WSBIS/NBIS system defines fair condition as "all primary structural elements are sound but may have minor section loss, cracking, spalling, or scour" [Refs. 27, 42]. However, this rating does not preclude the possibility that the condition of individual structural members may be deteriorated and require subsequent replacement. See Photo 15.

The steel truss approaches do not have a complete lateral load path to bring the lateral earthquake load from the deck level to the supports at the bascule pier [Ref. 1].

Photo 15: Steel Approach Trusses
Note condition appears to be fair.
(from *Echelon Engineering Inspection Report*, Ref. 18)

Concrete Approach and Abutment Foundations

In addition to the liquefaction risk described previously in the *Steel Approach Truss Foundations* section, the south earth-filled abutment settled after the Nisqually Earthquake in February 2001. See Photo 16. All concrete approach foundations were rehabilitated in the early 1970s, including replacement of the top portion of the timber piling.

Photo 16: South Abutment Settlement
Settlement at abutment due to the Nisqually Earthquake in February 2001.

Concrete Approach Piers and Abutments

Corrosion Induced Spalling
Corrosion-induced cracking and spalling is evident on the north and south approaches. Spalling of the concrete has been ongoing. Cracks at the end of pier caps have progressed over the time, and numerous areas exhibit the reinforcing steel, which is in some cases significantly corroded. The concrete has undergone complete carbonation from the surface inward ranging from ¾ to 1 inch. Carbonation reduces the pH of the concrete, which in turn reduces its effectiveness to act as a protection barrier against corrosion [Ref. 6].

Cracking
It is highly probably that the large deep cracks appearing along the pier caps and the numerous cracks perpendicular to the primary cracks are caused by expansive stresses due to the alkali-silica reaction [Ref. 6]. See Photo 17. Cracks are especially apparent at every third bent, where defective expansion joints in the roadway have allowed water onto the cap beam.

Photo 17: Concrete Approach Piers
Note large cracks appear along pier caps.

Alkali-Silica Reaction
Alkali-silica reactions have contributed to distress in the form of cracks. Repeated wetting and drying have accelerated the rate of reaction [Ref. 6].

Earthquake Damages
After the Nisqually Earthquake in February 2001, inspections found that multiple columns cracked in both the south and north approaches. The cracks appeared near the tops of columns, at bases, and a few feet below the ground. Inspections also found settlement of the span between the south abutment and Pier 2, and rail, rail beam and cap damage due to collision with the adjacent steel truss structure at Pier 13 [Ref. 41]. See Photos 18,19 and 20.

Photo 18: Concrete Approach Column
Note multiple cracks in column.

Concrete Approach Deck

Load Rating

A "fair condition" rating (5) was assessed for the deck in the *WSBIS Bridge Inspection Report* [Ref. 19]. A load rating analysis in 1994 indicated that the flat slab was adequate for carrying legal truckloads and overload truck 1. Overload truck 2 and the HS20 truck have rating factors of approximately 0.8 for the flat slab. The pier cap ratings were adequate for all vehicles except the HS20 truck, which is 0.8 [Ref. 14].

Chloride Ion Concentration

"The level of water-soluble chloride ions range between 360 and 610 parts per million. Although it is believed that water-soluble chloride levels are above 1.2 pounds per cubic yard (or 0.030%), the FHWA guidelines consider a chloride level above 2 pounds per cubic yard (or 500 parts per million) sufficient reason for deck replacement [Ref. 6]." Parts per million (ppm) can be relayed in terms of percentage by simply dividing the number of parts per million by 10,000. For example, 100ppm can be written as 0.010% and vice versa.

Photo 19: Concrete Rail and Slab Nisqually Earthquake Damage

Photo 20: Concrete Rail and Slab Nisqually Earthquake Damage Detail

Retaining Walls of Bridge Approaches

All these retaining walls are supported on spread footings. Widening of retaining wall joints caused by settlement and spreading of walls, was found after the Nisqually Earthquake in February 2001 [Ref. 41]. See Photo 21.

Photo 21: Retaining Wall Nisqually Earthquake Damage

Note settlement damage to retaining wall, resulting in widening of vertical joints.

Mechanical System

The Scherzer Rolling Lift Bridge Company of Chicago, Illinois designed the existing South Park Bridge machinery. In many ways, the South Park Bridge is a fairly typical double-leaf highway rolling lift bridge of this era. Originally, the Scherzer Company used rolled steel plate treads (usually less than 2 inches thick), but this design started to develop cracks. Revisions to this design used cast steel treads, this design did not eliminate the cracking problem. To solve the problem, the Scherzer Rolling Lift Bridge Company recommended rolled plate treads, but with thicker threads than used on the original design. The South Park Bridge constructed in 1929 incorporates this later design of rolled plate treads.

The South Park Bridge drive system is comprised of open frame motors, brakes, shafts, bearings and reduction gears, which are mounted on the moving bascule leaf span. The driving rack pinions are located with their axes at the center of the roll of the span and mate with straight rack sections mounted on the pier on either side of the bascule span. This mechanism pushes or pulls the span open and closed, respectively. This type of drive system is an improved design from an earlier Scherzer drive mechanism, which consisted of an operating strut driven by machinery mounted entirely on the pier.

The lugs and pockets on the existing bridge treads are no longer aligned, and numerous repairs have been performed to help realign the bridge. There are large areas of local damage at the tread plate (a flat steel track on which the rocker rolls) contact surfaces. At least one alignment pocket that is cracked (NW track) at the segmental track mounted along the circumference of the rocker, due to excessive stresses from a past misalignment problem. The horizontal girders that support the flat treads are inaccessible for inspection because they are encased in concrete. See Photos 22 and 23.

Based on a cursory review of the original design plans for the South Park Bridge, the existing (apparently original) machinery appears to have been mostly adequately designed for loading per AASHTO requirements. Only the racks had inadequate initial strength, but this is based on assumptions of material properties that should be confirmed by review of original shop drawings or material certifications. Due to the wear experienced over the life of the bridge, several gears appear to be close to marginal in their tooth strengths, again based on assumptions regarding material properties. Three of four pinions "E" (designation per Scherzer design drawings) have worn, which may indicate they are overstressed at maximum load. Several gears and shafts are supported in babbitted bearings, and the rack pinion shaft and other lower speed shafts in the drive train are supported in bronze bushings.

The Stafford Engineering *In-Depth Inspection Report* of June 1992 [Ref. 51] reports that the bridge's mechanical machinery has been well maintained over the years and is in generally good condition. Since Stafford Engineering's previous inspection in November 1986, new traffic gates were installed and debris that fell through the roadway and collected on racks, tracks and track mounting flanges is being removed on a regular basis. Some debris still collects at the live load reaction points and horizontal tracks, but more frequent cleaning prevents further corrosion of mechanical components.

In 1995, King County made repairs to the mechanical components as per recommendations stated in the Stafford Engineering report of 1992 [Ref. 51]. The differentials and bearings were rebuilt. King County also implemented a regular greasing and lubing program in 1998, to lengthen the service life of the mechanical components.

Photo 22: Existing Track Castings and Track Segmental Girders

Photo 23: Existing Segmental Girders and Track Casting Detail

Electrical System

The South Park Bridge's existing electrical power and control system equipment is mostly original. The panel board and switchboard equipment has historic value because it is among the last of its kind for this type of bridge. The main control panel is a live front, live back slate board with open contactors and exposed live parts. Replacement parts have long been unavailable, and numerous relays have been replaced with modern industrial relays that are not necessarily equivalent but perform the same function.

The tender's control desk and emergency generator are original. Numerous control desk indicator lights and pushbuttons have been replaced, but the drum control switches are original (see Photo 24).

Most of the electrical conduit and raceways are original and many show signs of corrosion. Original conduits are embedded in cracked concrete walls and are subject to moisture intrusion. Conduits corrode on the inside, and the resulting interior delamination may destroy brittle conductor insulation. Preventative maintenance has corrected some of the leaks in the conduit, but cracks in the concrete walls remain a cause for concern with leaks into the embedded conduit.

The operating reliability of the bridge would likely continue to decrease as the old electrical equipment continues to age, and proper maintenance would become increasingly difficult. Because many replacement parts can no longer be obtained, repairs require innovative and non-standard repairs by electricians. In addition, many conductors currently have no wire numbers, which makes it difficult to troubleshoot operation and control problems. Original wiring has brittle insulation that can easily crack if disturbed, increasing the scope of minor repairs.

The emergency generator is a gasoline engine driven, open-frame dynamo with exposed brush holders. The generator control board is an open-frame slate board with exposed electrical parts. It is presently not electrically connected to the drive system. As such, the emergency generator is not integrated with the drive system and therefore does not appear to be operational.

The submarine cable providing power to the bridge is currently in "very good condition". A meg test was performed on each of the cable's conductors, to check the insulation and each conductor's ability to carry current. A few conductors show some resistance but this is not unusual. If they continue to deteriorate, the conductors can be abandoned and some of the spare conductors can be used. Provisions should be made to replace the submarine cables or develop an alternate design that does not use these cables. Although the cable is in very good condition for the short term, it will not maintain this condition over the next 70 years.

The controls for the traffic gates are not original. The control relays are mounted in a freestanding enclosure on the lower floor next to the generator control board. The cast-iron traffic gate housings are probably original. The interior operating machinery was replaced in 1989 with hydraulic operators.

Photo 24: Original Control Desk

3. REHABILITATION OPTIONS

Based on the current operations and condition of the various bridge elements, the next step of this study is to develop options to rehabilitate the South Park Bridge. Most previous studies acknowledged that the bridge is nearing the end of its useful design life and assumed that the existing bridge would be replaced within the next ten to twenty years. As such, these studies addressed interim rehabilitative measures to alleviate distress to the bridge, or seismic vulnerability and possible rehabilitation solutions. These measures were "band-aids" that did not generally mitigate seismic hazards or operations and maintenance issues to a standard commensurate to a new bridge. Moreover, none of the studies attempted to combine the two (i.e. to minimize seismic risk AND mitigate operational issues through rehabilitation). This study's goal is to rehabilitate the bridge for the long-term and to meet current AASHTO seismic standards [Ref. 45].

To conduct this study, it is necessary to investigate additional rehabilitation measures beyond those evaluated in previous reports. In particular, the investigation examined measures to rehabilitate the existing bridge to <u>extend</u> the useful life of the bridge and to make improvements to meet seismic safety codes. Operation and maintenance issues also are addressed due to the deteriorated condition of the bridge.

This chapter describes the design considerations for the rehabilitation alternative, the design approach for alternative options, and the specific scope of the construction work for two key options to rehabilitate the existing South Park Bridge.

Design Considerations of the Rehabilitation Alternative

Several basic parameters were considered in studying the Rehabilitation Alternative, including environmental impacts, the bridge's historic nature, ship channel navigation clearances, and seismic performance.

Environmental Impacts

Environmental impacts will be evaluated in the EIS for the South Park Bridge. Several environmental concerns, however, were anticipated as the Rehabilitation Alternative was developed. Boeing warehouse and manufacturing facilities reside on the north embankment of the Duwamish, near the north approaches to the South Park Bridge. Because of many years of heavy manufacturing, the Duwamish River has been designated a Superfund site. The river provides a natural habitat for endangered salmon species that spawn and migrate along the waterway. As such, construction methods that minimize disturbance to contaminated soils and removal of spoils were preferred. In addition, minimizing the number of foundations and pier structures in the Duwamish River were considered.

Historic Nature of Bridge

The South Park Bridge is listed on the National Register of Historic Places. It is the only operational example of a Scherzer Rolling Lift Bascule bridge in the state of Washington. In the *King County Landmark Registration Form* filed, the Scherzer rolling mechanism is identified as contributing to the bridge's historical significance [Refs. 22, 23]. See Figure 2.

The Scherzer rolling lift mechanism has a unique method of lifting a bridge span. By rolling back as well as rotating, the leaves tend to clear a wider channel opening than a simple trunnion type bascule bridge of the same span length. Although not as common today as the trunnion bascule bridge, it remains a viable lift mechanism for bascule bridge types.

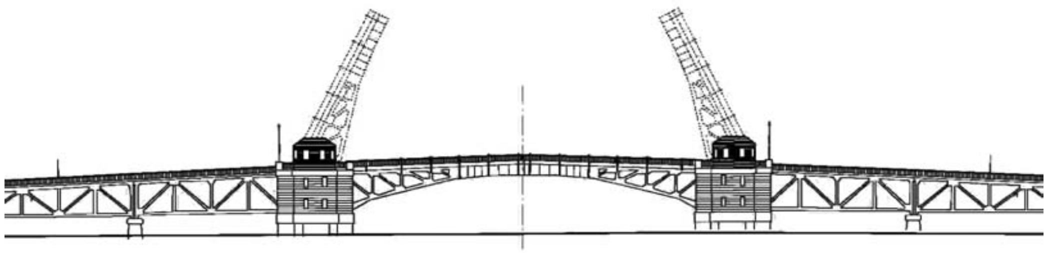

Figure 2: Sketch of Existing Bridge

The Rehabilitation Alternative's goal is to preserve the existing bridge as much as possible, and rehabilitate or replace-in-kind the structural elements that are beyond repair or require upgrading due to seismic or other safety concerns. The Rehabilitation Alternative seeks to maintain as many architectural and functional features as possible without compromising seismic safety or bridge operations and maintenance. The Scherzer rolling lift mechanism is preserved in Options 1 and 2.

Ship Channel Navigation Clearances

The U.S. Coast Guard regulates current shipping channel navigation clearances for the Duwamish Waterway. Currently, the waterway runs under the existing South Park Bridge at a skew angle. The clear channel width between pier protection systems is currently 118 feet at water level. The minimum vertical clearance for the existing bascule bridge, at the center of the span, when closed is approximately 34 feet from Mean High Water (MHW) level [Ref. 44]. See Figures 3 and 4.

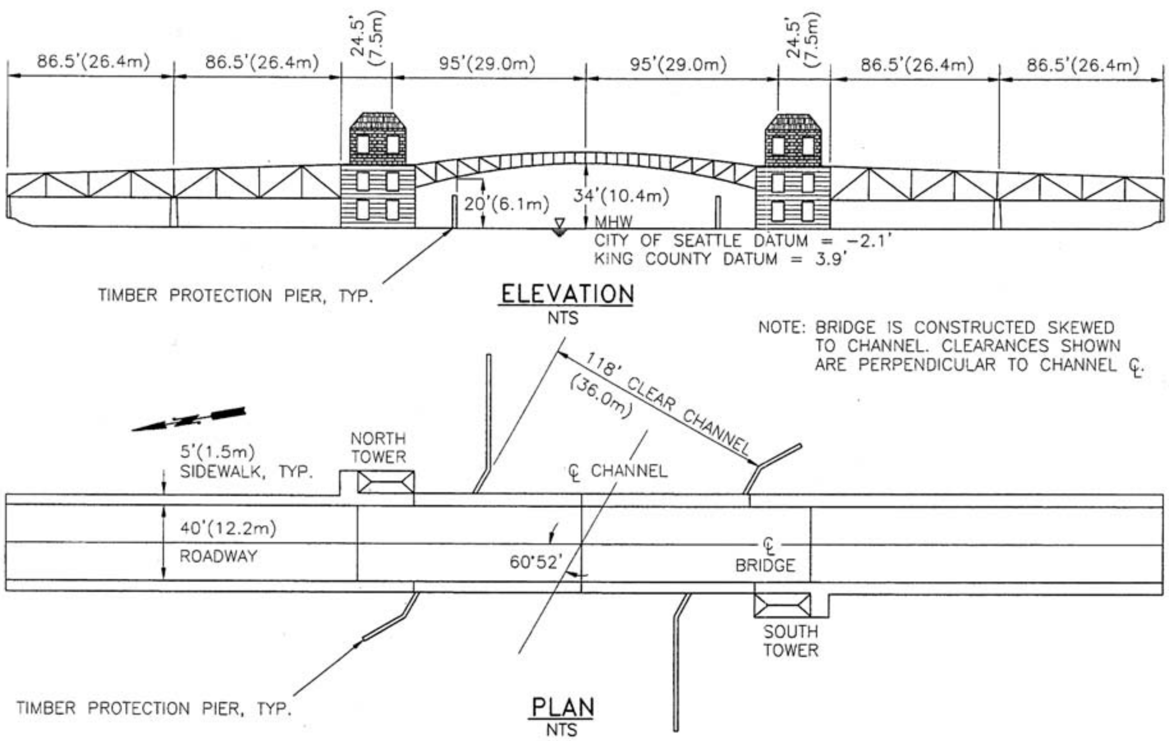

Figure 3: Existing Navigation Channel (Bridge Closed)

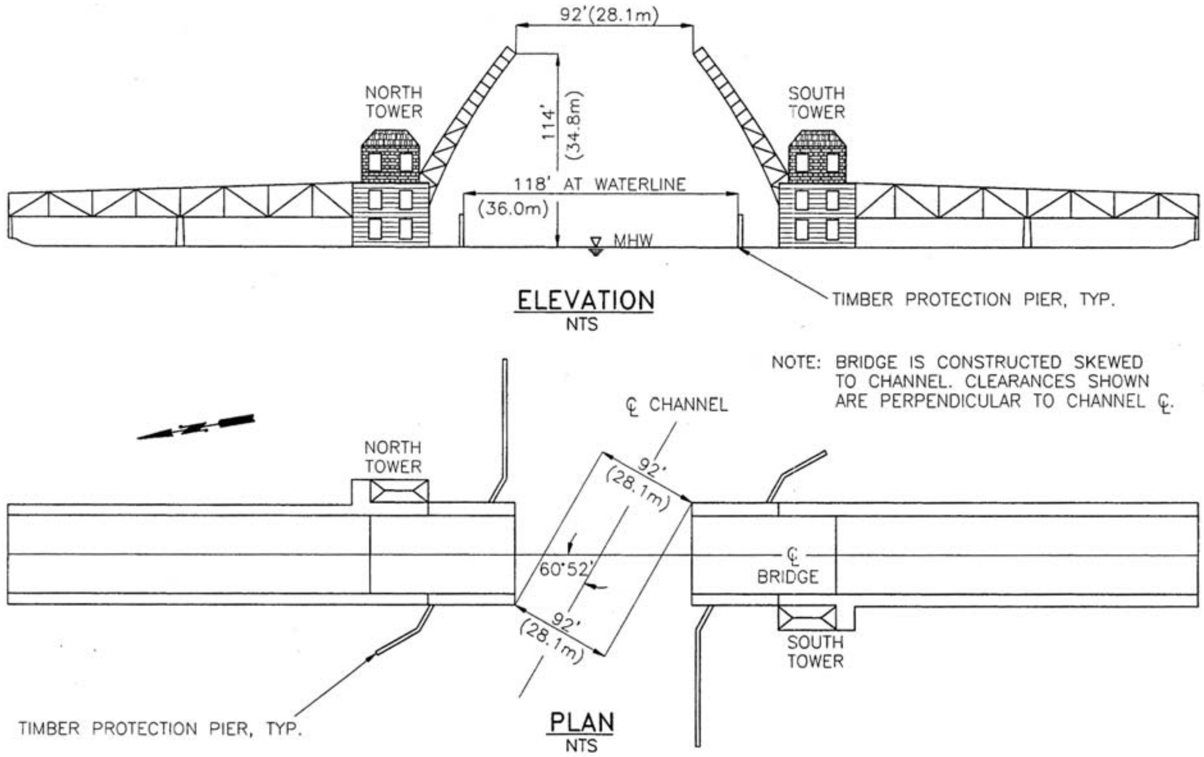

Figure 4: Existing Navigation Channel (Bridge Open)

Seismic Performance and Lifeline Status

One of the most basic parameters in seismic design is to determine the bridge's AASHTO Importance Category. The South Park Bridge is not on the National Highway System, and therefore is not a federal- or state-mandated lifeline. This bridge is not currently listed as part of King County local lifeline system [Ref. 43]. Hence, by AASHTO's current definition [Ref. 45], the South Park Bridge Importance Category should be classified as "other bridges" and the required level of seismic performance is considered "no collapse" for the AASHTO design earthquake with a return period of 475 years. This means that "exposure to shaking from [a] large earthquake should not cause collapse of all or part of the bridge. Where possible, damage that does occur should be readily detectable and accessible for inspection and repair" [Ref. 45].

AASHTO also states the following: "In classifying a bridge, consideration should be given to possible future changes in conditions and requirements." Because the South Park Bridge is currently a link between two King County-designated lifelines located on both sides of the river between two jurisdictions, it is possible that King County may upgrade the bridge to the lifeline status in the future. Because river crossings are somewhat limited across the Duwamish Waterway, it would be logical to treat the South Park Bridge as a lifeline structure. The City of Seattle currently classifies the bridge as a lifeline because it is a priority snow-removal route.

Design Approach

The proposed Rehabilitation Alternative would provide a structure that has the same overall width before and after rehabilitation (see Figure 5). Currently, the bridge is 50 feet wide. The pavement is divided equally into four non-standard 9.5-foot lanes, two lanes in either direction. To either side of the pavement, there is a raised 6-foot sidewalk, including curb and gutter.

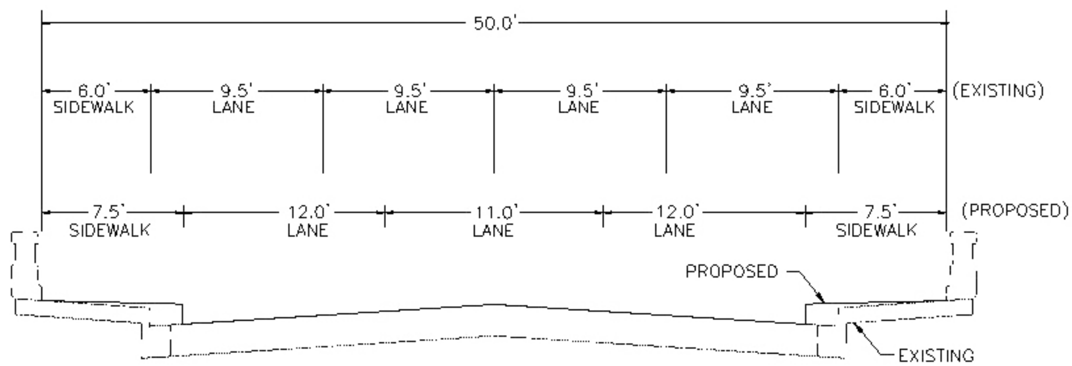

Figure 5: Existing and Proposed Typical Roadway Cross-Section

The proposed configuration of the bridge would accommodate three traffic lanes that meet current code requirements. The two outside lanes would be 12 feet wide and the center lane would be 11 feet. This proposed configuration would be striped for two southbound lanes and one northbound lane. To either side of the pavement, there would be a raised 7.5-foot wide sidewalk to serve both pedestrian and bicycle traffic. This configuration meets forecast traffic demand for the next 20 years, despite the reduction in the number of lanes across the bridge.

Once the lane and sidewalk configuration for the rehabilitation of the bridge was decided, potential options for rehabilitating the existing bridge were investigated. In determining the feasible rehabilitation options, three basic questions were asked:

1. Which structural components of the bridge can be saved?
2. How can these components be rehabilitated?
3. Is the proposed rehabilitation constructible?

The basis for answering the first question comes from a thorough review of condition reports, previously conducted studies, and field visits to the South Park Bridge. Assessment of each major component determines whether rehabilitation is feasible. Further studies and preliminary calculations were performed to determine how major components would be rehabilitated, and one or more conceptual strategies were identified. Geometric constraints, constructibility issues, and the design parameters described previously were considered in order to determine the feasibility of each conceptual rehabilitation strategy. If rehabilitation were deemed not feasible, then the replacement of the component would be the last resort after exploring all other methods.

Based on the above approach to develop rehabilitation options for the South Park Bridge, two distinct rehabilitation options were developed and studied in detail. The objectives of these options were:

- Option 1: To preserve most of the original substructures without removing the bascule leaves during construction, in order to minimize interruption to vehicular, bicycle and pedestrian traffic.
- Option 2: To replace the bascule piers and foundations, concrete approach structures, and steel truss approach piers. The bascule leaves and approach trusses would be temporarily removed, refurbished and reinstalled during the construction. This approach would require closure of the bridge for the majority of the construction period.

The following subsections describe these rehabilitation options in detail. The proposed rehabilitation options are described in detail for the following major structural components:

- Bascule Pier Foundations
- Bascule Piers
- Bascule Leaves (Truss Superstructure and Deck)
- Steel Truss Approach Substructure (Piers and Foundations)
- Steel Truss Approach Superstructure (Truss and Deck)
- Concrete Approach Structure (Piers, Foundations, and Deck Slab)
- Retaining Walls Along the Approach Roadway
- Mechanical and Electrical Systems

Rehabilitation Option 1

This option was studied first, to determine the following:

- Would it be feasible to keep the existing steel bascule spans and steel truss spans in place during rehabilitation? The purpose of keeping the superstructure in place is to provide an alternative that would minimize interruption to vehicular, bicycle and pedestrian traffic.
- What would be the maximum amount of existing bridge components that could be rehabilitated without replacing them?
- What would be the approximate cost for this rehabilitation approach?

The findings and the proposed rehabilitation approach for Option 1 are described below.

Bascule Foundations

The method of rehabilitating the bascule foundations would significantly impact the rehabilitation approaches to the rest of the structure. Because of this, the first major step of the rehabilitation study is to find out if the existing bascule pier footings could be rehabilitated and could meet the requirement of maintaining the existing 118-foot navigational channel width.

A previous foundation study indicated that differential settlement has been one of the causes of operational difficulties for the bascule leaves [Ref. 4]. This settlement is primarily due to the fact that the timber piling on the north bascule pier did not reach competent glacial till (it is short by approximately 10 to 20 feet), so the piles do not have sufficient load bearing capacity for the designed dead and live loads [Ref. 13]. Further settlement and foundation issues may have been caused by possible liquefaction and loss of bearing in the piles, due to channel dredging over the years [Ref. 13]. Leaf misalignment caused by differential settlement has further exacerbated wear on the tracks and the rolling lift mechanism, which in turn has caused the bascule piers to crack and pier walls to splay [Ref. 4]. Post-tensioning between bascule pier walls was installed in the counterweight pit in 1982 to alleviate splaying [Ref. 13]. However, it is clear that unless the fundamental settlement issue in the bascule piers is addressed, existing defects in the piers and the operation of the bascule leaves would most likely continue to worsen. These types of operational issues would need to be thoroughly mitigated for a valid comparison between all structural alternatives.

The existing bascule pier foundations do not have sufficient vertical and lateral load resistance capacity if a major design level earthquake occurs. The potential foundation settlement and drift during an earthquake may damage the entire bridge beyond repair. A previous study recommended "provid[ing] new foundations to provide adequate vertical and lateral resistance" [Ref. 5]. However, the recommended "new foundations," which were extensions to the existing foundation, would use four 6'-0" shafts (one near each corner of the existing footing), which would encroach into the existing navigational channel.

Based on this study, rehabilitation of the bascule pier foundations is proposed, in which seismic overturning and lateral forces would be mitigated through the addition of large diameter piles. In order to maintain the current 118 feet navigational channel width, irregularly shaped footing extensions, which would "collar" around the existing footings, were considered (see Figure 6). Preliminary calculations indicated that at least nine shafts of 10-foot diameter would be required at each bascule pier foundation to provide sufficient vertical load carrying capacity and lateral load resistance. It would be extremely difficult to place the two shafts along the bridge centerline adjacent to the north and south pier protection, because a hole would have to be cut in the bascule leaf and then repatched.

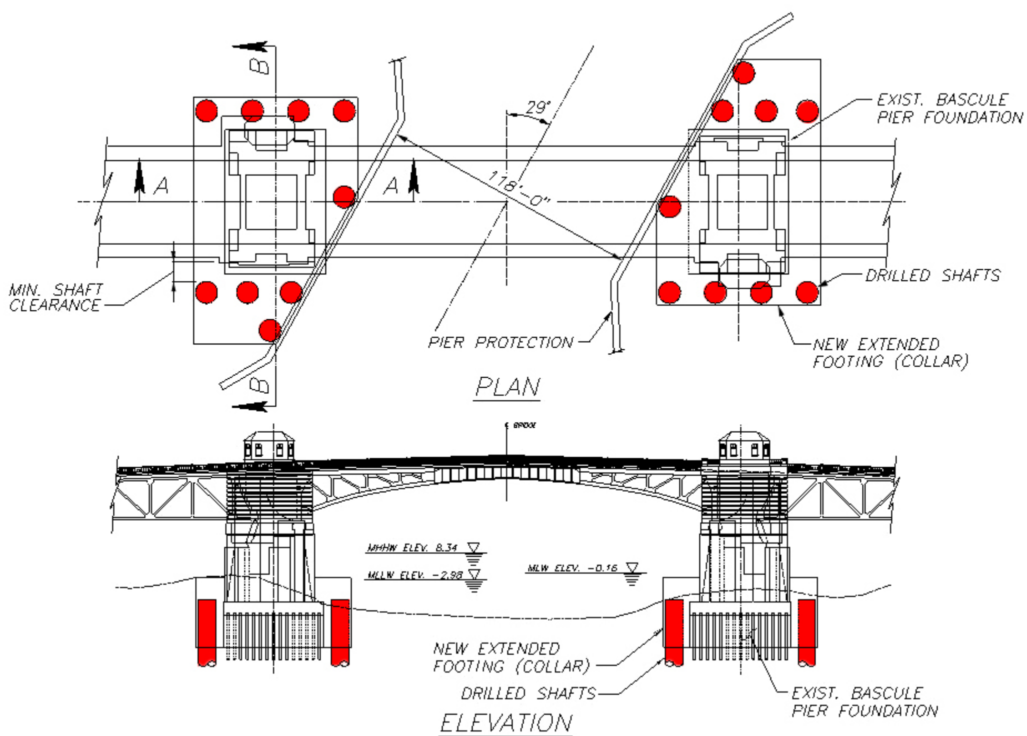

Figure 6: Bascule Pier Foundation – Rehabilitation Option 1 (Plan and Elevation)

The purpose of the collar is to reinforce the existing pier foundation. As such, if the existing foundation settles after rehabilitation, some of the vertical loads from the existing footing would be transferred to the collar. To achieve this, the existing footing and the new collar must be made to act together. This can occur if the reinforcement between the existing footing and new collar is continuous and creates a "sandwich" with the existing footing. The most efficient way to do this is to install shear dowels and post-tensioning. Considering the existing footing is 6 feet deep, the rehabilitation is envisioned to have post-tensioning tendons at the top and bottom of the existing footing to connect the collar to the existing footing. Figures 7 and 8 show the longitudinal and transverse section views. Figure 9 is a conceptual drawing of the exterior of the bascule piers for this rehabilitation option.

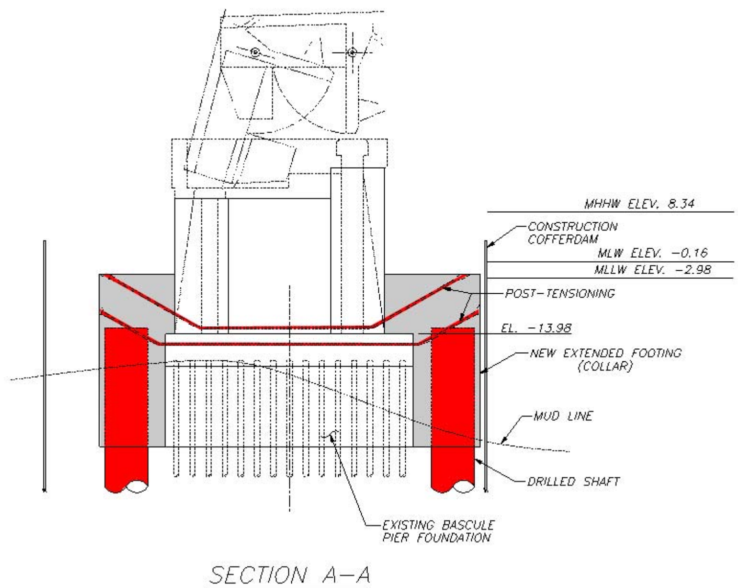

Figure 7: Bascule Pier Foundation – Rehabilitation Option 1 (Detail A)

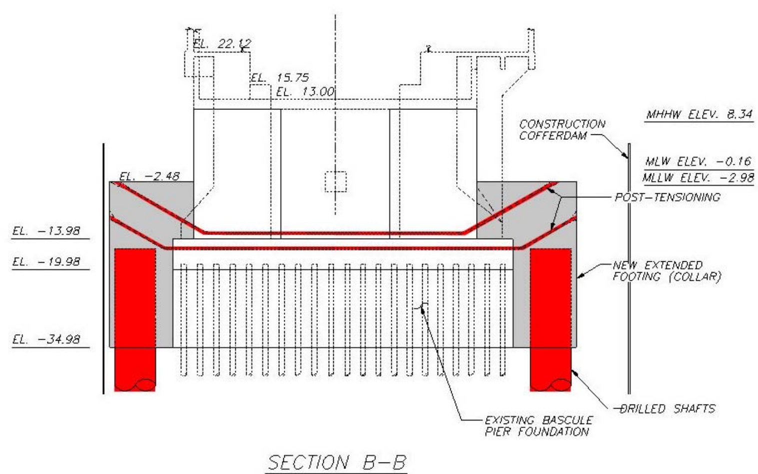

Figure 8: Bascule Pier Foundation – Rehabilitation Option 1 (Detail B)

Figure 9: Bascule Pier Foundation – Rehabilitation Option 1 (Exterior Sketch)

The existing foundation is quite long and wide (approx. 46' x 66'). Cofferdams at both bascule pier locations would be required for constructing the footing collars (see Figures 7 and 8). Dewatering inside the coffer would need to be done before the drilling operation starts. Hence, coring through the existing pile cap and constructing the collars would be a time-consuming operation because of required continuous dewatering and the difficulty of drilling holes for post-tensioning through the existing 66-foot-wide pile caps. The close proximity that would be required in working with the existing bridge foundations would create the possibility of disturbing the existing pier(s). In addition, installation of an Earthquake Drain System along side of the existing foundations is recommended to stabilize the existing foundation and to provide additional vertical load bearing capacity.

Bascule Piers

As described in Chapter 2, condition reports and studies collected over the past 20 years outline the poor and deteriorating condition of the bascule piers [Refs. 4, 8, 18, 19, 20, 26, 27, 47, 48]. The spalling and large cracks include large vertical and diagonal cracks in the pier walls, corrosion occurring in the rebar in the pier walls, and the damage due to chemical reactions occurring in the concrete pier walls.

A previous study found that "the vertical load bearing capacity at the north pier appears marginal. Lateral-load-resisting capacity of the pier foundation appears inadequate. Severe tilting and loss of superstructure is possible in a major earthquake" [Ref. 5]. Another investigation, based on an earthquake with a return period of 190 years, found that the maximum tensile stress in the pier wall (107 psi) would be much higher than its capacity (49 psi). Even worse, the response spectrum factor of the 475-year earthquake would be approximately 2 to 5 times greater than the 190-year earthquake [Ref. 1].

Vertical tie-downs and post-tensioning of the pier walls to the foundation, as previously proposed [Ref. 1], would not be sufficient to meet project requirements [Ref. 12]. If adequate pier rehabilitation is not implemented to provide confinement for the pier walls, the vertical and diagonal cracking would likely continue to worsen with the rolling action of the bascule girders and eventually the walls would fail due to shearing.

To mitigate cracking, differential movement, and splaying in the pier walls, PB investigated a “sandwich” rehabilitation solution. The feasibility of using a grillage of steel beams encased in concrete (with cathodic protection or coatings to prevent further acceleration of corrosion, etc.) both inside and outside the bascule pier walls is proposed to “sandwich” and confine the existing pier walls. See Figure 10.

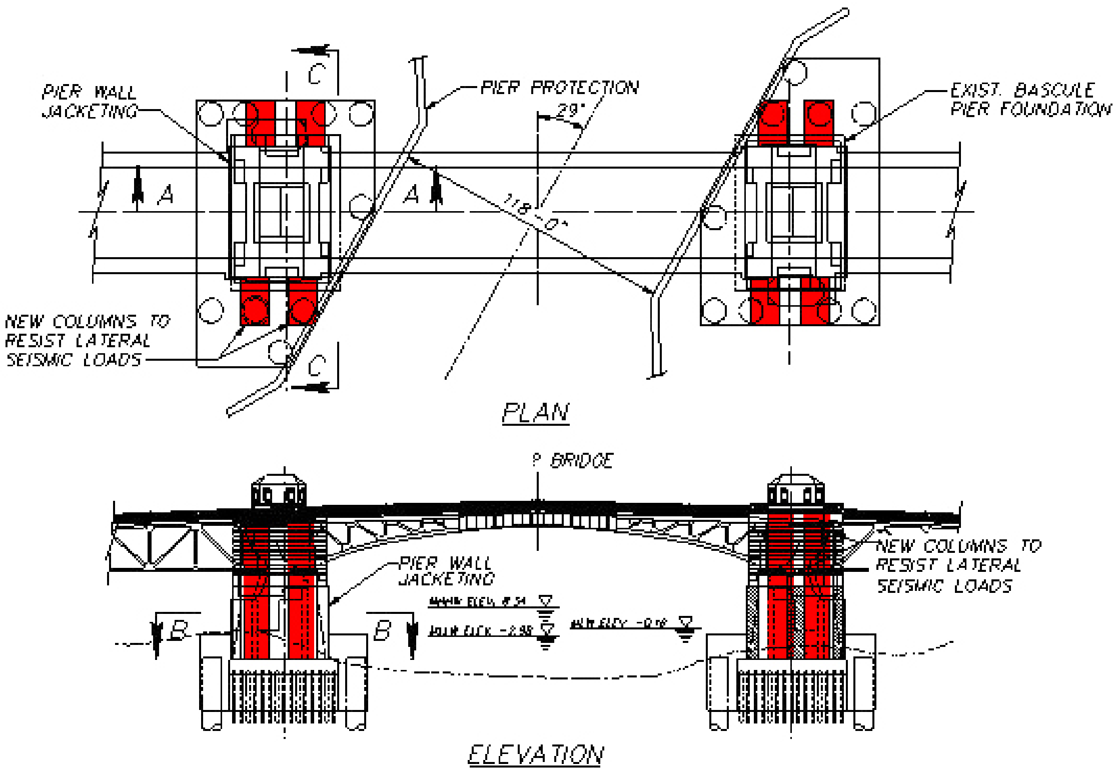

Figure 10: Bascule Pier Wall – Rehabilitation Option 1 (Plan & Elevation)

The conceptual proposed structure required to confine the pier walls is comprised of steel plates and channel sections, configured in a grillage pattern, and closely spaced on either side of the walls. The close spacing and steel members were considered in order to lend adequate stiffness to the grillage, as compared to the thick pier walls. The grillage and plate systems would be tied to one another at regular intervals with post-tensioning rods to provide confinement for the pier walls. See Figures 11 and 12.

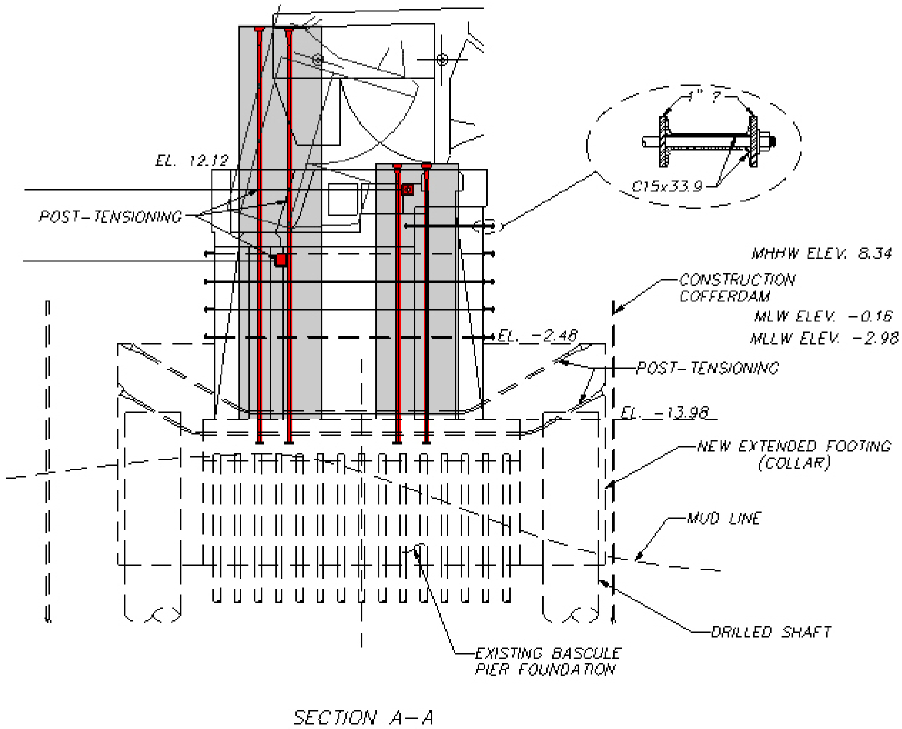

Figure 11: Bascule Pier Wall – Rehabilitation Option 1 (Profile)

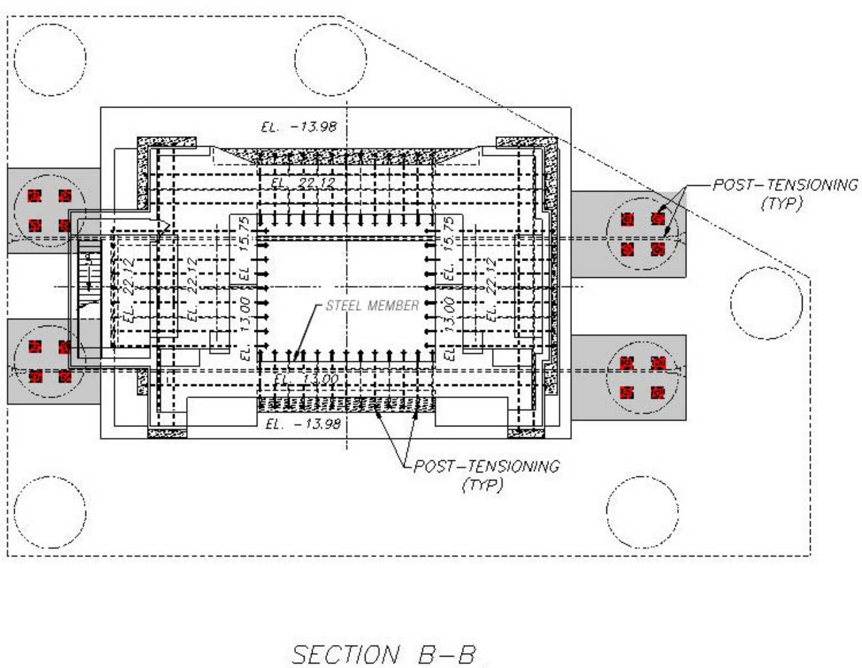

Figure 12: Bascule Pier Wall – Rehabilitation Option 1 (Plan Detail)

The rehabilitation of bascule fascia wall would be implemented, as recommended in *Seismic Study of 14th Avenue South Bridge* [Ref. 1]. Section 6.1.2 of this report recommends two braced frames be installed at the bascule pier to reinforce the fascia wall. In addition, high strength tie-downs should be placed in the bascule walls to create vertical compressive stresses to close or reduce the width of the existing horizontal cracks in the bascule wall. The severely deteriorated concrete near the inlet would be replaced with new concrete.

Four additional columns would be constructed and attached to the existing pier walls. The vertical post-tensioning in the columns and the horizontal post-tensioning near the front and back pier walls would act as a frame that can transfer the seismic induced lateral forces from the superstructure down to the new collar footings. See Figures 9, 11, and12.

Track girder and counterweight restrainers, as recommended in the Imbsen Report, Section 6.1.6, would also be installed. The track girder would help the existing shear lugs prevent slippage of the track girder on the track due to an earthquake. The counterweight restrainers would restrain transverse and downward movement of the counterweight.

This approach to rehabilitation for Option 1 would basically result in a repair of the exterior surface of the operator's houses. Continuing deterioration of the old structure, however, would require on-going maintenance to preserve the historic character of the structure. Similar roof tiles and window mullions would be used in the rehabilitation to preserve the existing architectural look of the structure. Moreover, the service life of the operator's houses is uncertain. The reinforcement provided by the collar to the lower portions of the bascule pier would not extend to the operator's houses. In addition, the already weakened condition of the structure of the operator's house would not likely allow modification of the structure, i.e. potential addition of a new window to improve ventilation. Such a modification, if desired, would also need to be evaluated for consistency with the current historic character of the building.

Bascule Leaves (Truss Superstructure and Deck)

Because the superstructure is in adequate condition (per inspection reports), it is envisioned that the truss superstructure can be cleaned, painted and re-used. If after thorough cleaning, some truss members too deteriorated to be re-used, they should be either strengthened or replaced with new, similar members.

The rehabilitation activities recommended in the 2001 Imbsen Report [Ref. 1] would also be implemented. Section 6.1.1 of this report recommends new double angles should be added to the frame laterals. Some vertical members of the truss should be replaced with large size members. In addition, a wide flange beam would be added to the bottom chord of the truss. These improvements would improve the lateral load path between the deck level and the bearing of the bascule span.

Steel Truss Approach Substructure (Piers and Foundations)

Based on the condition reports, the steel truss approach piers show significant deterioration above and below the waterline, including spalling, chloride attack [Ref. 18], and alkali-silica reaction. The condition of the timber piling is unknown [Ref. 4]. Preliminary review of the as-built drawings revealed that the piers are minimally reinforced and are not detailed for confinement and transfer of lateral loads, particularly large seismic forces. To resist lateral force during an earthquake, new pier columns supported by large diameter drilled shafts would be constructed adjacent to the existing piers and connected to the existing pier caps. The existing pier caps would be strengthened and post-tensioned. A new diaphragm wall would be constructed between the existing pier columns to resist lateral seismic loads during a major earthquake event. See Figures 13, 14, and 15.

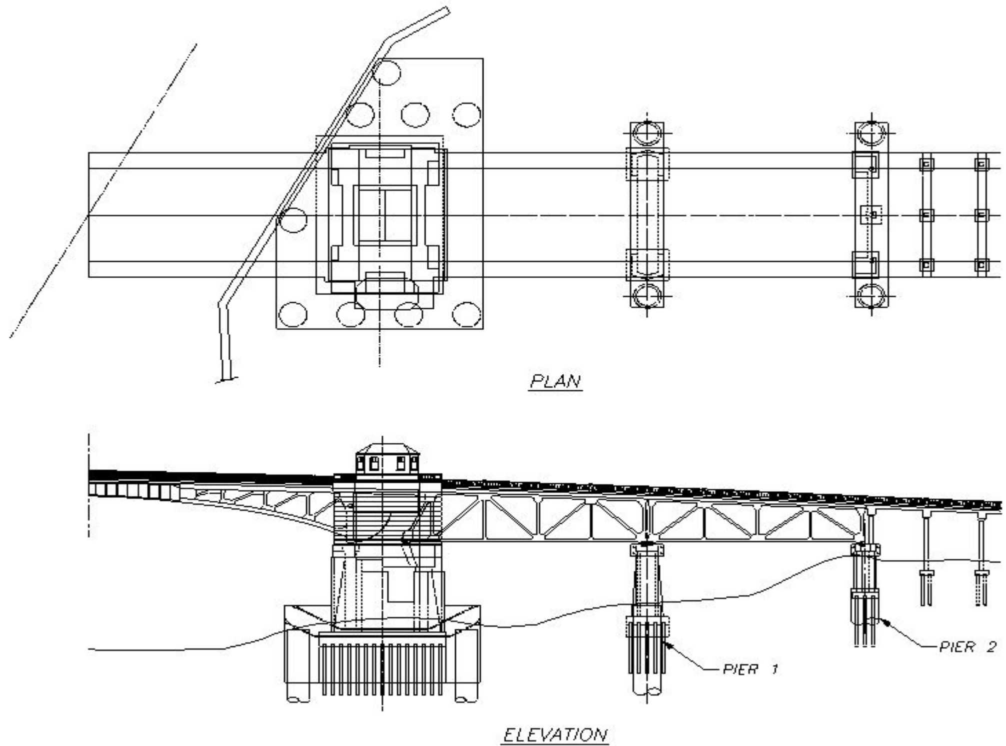

Figure 13: Steel Truss Approach – Rehabilitation Option 1

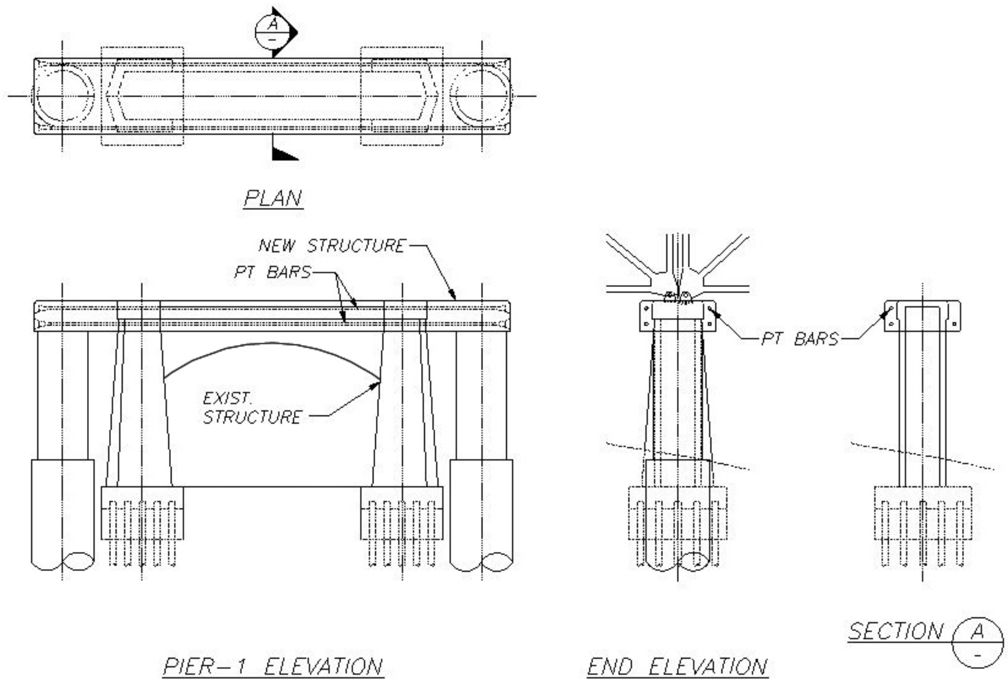

Figure 14: Steel Truss Approach, Pier 1 – Rehabilitation Option 1

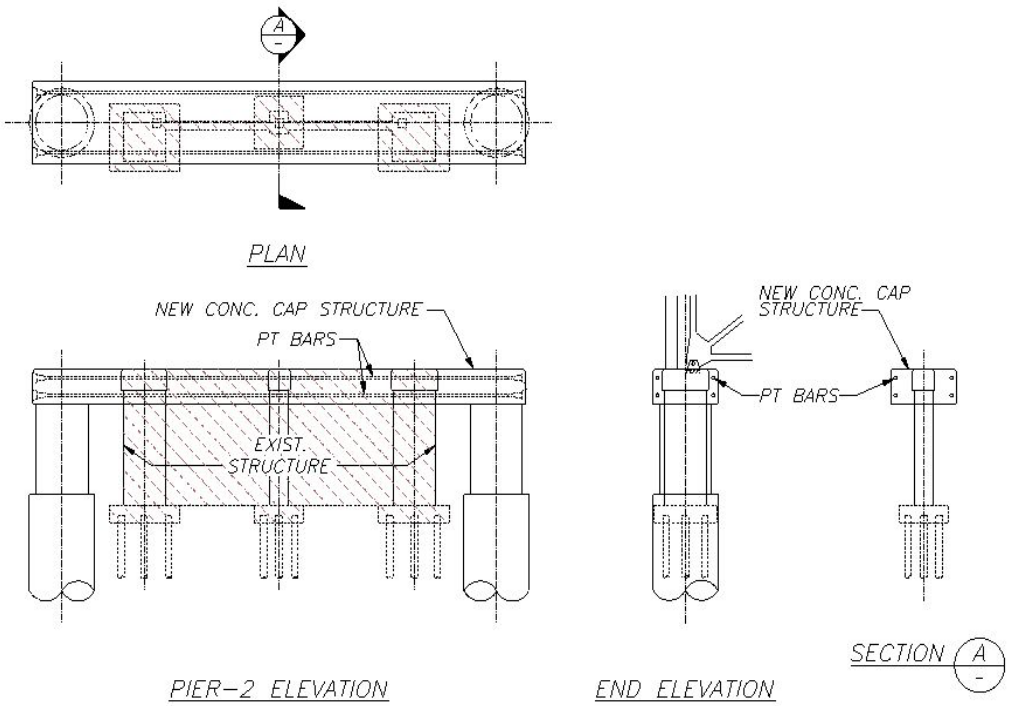

Figure 15: Steel Truss Approach, Pier 2 – Rehabilitation Option 1

Steel Truss Approach Superstructure (Truss and Deck)

The steel approach span trusses appear to be in adequate condition. The *WSBIS Bridge Inspection Report* shows that the superstructure is in fair condition (the 2002 rating is 5.0 out of 8.0) [Refs. 19, 27]. The truss would be cleaned, painted, and re-used. If the condition of individual truss members is too far deteriorated, these members should be either strengthened or replaced with new, similar members.

A previous study found that the "steel trusses are inadequately restrained and the pile foundations are inadequate" (in regards to the vertical loads and seismically induced lateral loads) [Ref. 5]. The Imbsen Report [Ref. 1] found that "the steel truss approaches do not have a complete lateral load path to transfer lateral seismic loads from the deck level to the supports at the bascule pier." The recommended seismic restraint features in the Imbsen Report Section 6.1.3, Truss Approach Span Superstructure, would be implemented. The seismic restraint features would consist of "one braced frame installed on each side of the pier to brace the truss, high-strength rod restrainers installed between Truss Approach 1 and Truss Approach 2, additional anchor bolts installed at the fixed support, a transverse shear key placed at the top of Pier 1, and a longitudinal slot in the new concrete block at the top of the pier to allow free longitudinal relative movement between the bottom strut and the concrete block." A similar shear key would be placed at the top of Pier 2. [Ref. 1]

Concrete Approach Structure

Piers and Footings

The south concrete approach sustained damage from the Nisqually Earthquake of February 2001. The latest inspection reports show that multiple concrete pile/columns on the south approach and two bents of the north approach have cracks near the top and/or bottom. The south abutment settled, shifting the roadway and spreading retaining walls and rails. Timber shoring currently supports Pier 2 and the abutment of the south concrete approach due to damage from the Nisqually Earthquake [Refs. 19, 41].

The concrete of the piers and abutments is spalling and cracked [Refs. 6, 7, 19, 41]. In 1995, repairs were made to multiple pier caps. As is typical with spall repairs, the crews attempted to chip away the bad concrete on the cap until sound concrete is reached. Chipping away at spalls and cracks revealed that the interior concrete is also in poor condition. On the west end of bent 4 on the north approach, concrete was so deteriorated that progress on the cap had to be stopped because the chipping was approaching the first column. This would have resulted in chipping away the entire cantilevered portion of the cap (see Photo 25). This investigation determined the deterioration was not due to corroding around the concrete rebar, but rather to uniformly poor material throughout the concrete section. For each cap repair, a new cage of No. 5 bar was doweled in before pouring new concrete. Every third bent is especially bad, because the expansion joints have leaked water onto these caps for years. The condition of the caps at bents 4, 7, 10, and 13 (abutment = bent 1) were worse than the other non-expansion joint caps (see Photo 26). In the late 1990s, all of these caps were repaired under expansion joints on both approaches. Further review of as-built drawings also show that pier reinforcement is sparse and inadequate for providing the confinement and detailing necessary to resist seismic loads. A previous study found that “the system…may fail in a major earthquake” [Ref. 5].

Photo 25: Unsound Concrete Removed During Repair of Bent 4 of the North Approach

Photo 26: Unsound Concrete Removed During Repair of Bent 7 of the South Approach

In the early 1970s, the north and south approaches underwent improvements to remedy unsound piles. The superstructure was temporarily supported on shoring assembly that was placed around the existing column so the footing could be excavated. The original top portion of unsound piles were cut off, and replaced with reinforced concrete blocks. (See Appendix A for reference to as-built drawing No. 3179, "Repair to Column Footings.")

The rehabilitation effort would be the same as recommended in the Imbsen Report [Ref. 1]. Section 6.1.5 of this report recommends that each of the four portions of the approach (comprised of three-continuous spans) be reinforced with cross-braces and grade beams along the longitudinal and transverse directions. The braces would be connected to the cap beams and grade beams to avoid the transfer of large shear to the columns. In addition, rod restrainers would be installed at the expansion joints. This approach to the rehabilitation would alter the historic architectural character of the existing bridge. The existing span lengths, however, would be preserved. The timber shoring currently supporting some of the spans would be replaced with concrete shoring.

<u>Deck Slab</u>
The existing reinforced concrete deck slab is mostly in fair condition, with an overall deck rating of 5 out of a total of 8, based on the *2000 Bridge Inspection Report* [Ref. 19]. The deck is worn with numerous cracks and needs a new concrete overlay.

The under side of the deck should be cleaned, and cracks should be repaired using epoxy injection. The rod restrainers would be implemented at the expansion joints, as recommended in the Imbsen Report [Ref. 1].

Soil Improvement

To avoid potentially expensive problems due to liquefaction and lateral spreading of the foundations, Earthquake Drains or soil compaction grouting is recommended as a ground improvement along both sides of the bridge foundation. According to the geotechnical engineer's (Shannon and Wilson, Inc.) recommendation, the ground improvement should be applied to an area that starts at each riverbank and extends 50 to 100 feet away from the waterway and 30 to 40 feet beyond the bridge width in an east-west direction.

Retaining Walls

Retaining walls along the south approach were rotated and cracked during the Nisqually Earthquake. Tieback or soil nailing with a cast-in-place reinforced concrete face in front of the existing wall are recommended to restore the wall. See Figure 16.

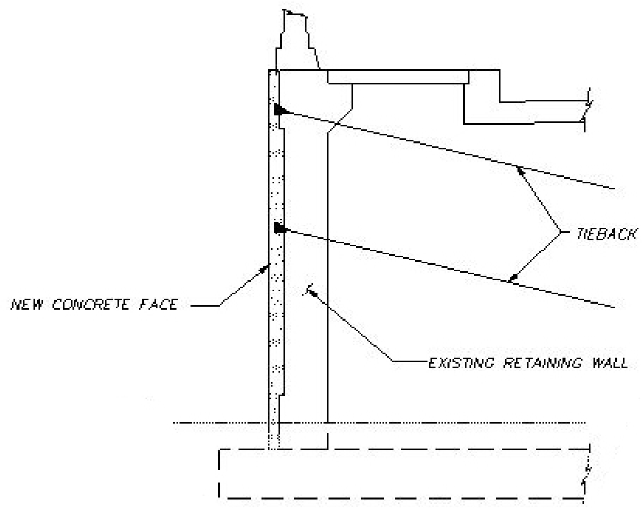

Figure 16: Retaining Wall – Rehabilitation Option 1

Mechanical System

A few gears in the existing mechanical system appear to be exceptionally strong and could probably last over 50 to 75 years. Wear on them, though, would add to the rate of wear of mating gears, and so they should be replaced to assure smooth operation for a reasonable length of time. However, the entire machinery package cannot be rebuilt in kind to guarantee service life commensurate to a new machinery system.

The machinery installation, as presently configured, would likely need some major repairs in the next ten years, including replacement of various portions of the open gearing and bearings. If the bridge were to be rebuilt, all gears, shafts and bearings should be replaced. Bronze should be used for all machinery shaft bearings, and all materials should meet current AASHTO movable bridge specifications. With these repairs and proper maintenance, the machinery would be expected to last 25 years without major repairs. The existing machinery bearing frames would be expected to last 70 years, but the rack girders (and most likely the machinery supports and segmental and horizontal track girders) would be expected to have only a 30- to 40-year service life.

For an estimated long-term service life, the two choices from a mechanical machinery standpoint are: 1) in-kind rehabilitation of machinery (25-year life), or 2) replacement of existing machinery with new modern design enclosed drives (35-year life). The targeted 70-year-life criteria would necessitate replacement of in-kind machinery twice in the life of the bridge and replacement of modern machinery once in the life of the bridge. It must be understood, these expected machinery lifetimes are based on the correct design, fabrication and installation of new machinery regardless of type.

Moreover, maintenance should be commensurate with this type of machinery. Maintenance is much more expensive for open gearing than for enclosed drives, because the reduction gears (particularly the higher speed gears) must constantly have gear grease reapplied to their teeth to avoid excessive wear. Ideally, these gears should be re-lubricated after every bridge operation, but twice weekly maintenance is assumed to be adequate. For an enclosed drive, maintenance once a month is adequate. Bearings do not need intensive lubrication because they tend to hold their lubricant better than open gears. Once a month should be adequate for re-lubricating bearings, including trunnion bearings if used. The long-term maintenance cost of in-kind rehabilitation would be much higher than replacing existing machinery with modern machinery with enclosed drives. Lubrication is optional for rolling-lift tread plates and racks and pinions.

Electrical System

The electrical power and control system on the South Park Bridge does not comply with the current National Electrical Code. It would not be practical to restore the current system due to a lack of replacement parts and skilled labor knowledgeable of this type of historic electrical system. Many conduits housing the control circuits are embedded in the cracked concrete walls, and water intrusion in the conduits has been a problem in the past. The electrical equipment is potentially an electrical hazard and should be replaced if the bridge is to remain in service.

The traffic signals and gates should be replaced to improve reliability and safety. Although the traffic gates were modified with new hydraulic operators in 1989, they should be replaced as part of the first of the two major complete 35-year rehabilitation programs for the bridge.

Asbestos was commonly used in electrical equipment and in insulated wiring during the era in which this bridge was built. As such, appropriate precautions should be taken during removal of the electrical equipment.

The recommended electrical power and control system assumes the bridge leaves would be driven by enclosed machinery comprised of two 125 hp motors on a common input shaft for each leaf. A single motor would operate each leaf of the bridge. The second motor would provide 100-percent redundancy should the operational motor fail. The controls would be set up to alternate the motors for even wear. The motors should be shunt wound d.c. motors on four quadrant silicon-control rectifier (SCR) drives, or a.c. squirrel cage induction motors on vector-controlled solid-state drives. All of the Seattle ship canal bridges have d.c. motors and drives, as does the First Avenue South Bridge. Because the City of Seattle may eventually own and operate this bridge, the d.c. motors and SCR drives are recommended for consistency.

The bridge operation should be controlled by a programmable controller-based control system. The control desk should be similar to the Seattle ship canal bridges to allow for easier rotation of substitute personnel. This recommended replacement of the historic control panels would also provide an opportunity to reconfigure the layout of the operator's house. Consideration of this modification, however, should be evaluated for consistency with the historic character of the structure.

The electrical service should be backed up with a diesel engine-driven generator.

The South Park Bridge power and control wiring to the opposite side of the Duwamish Waterway is installed using submarine cables. Submarine cables, however, were not permitted on the First Avenue South Bridge by environmental regulators. Separate electrical services and emergency generators were installed on both sides of the waterway. A tunnel was bored under the river and the control cables were routed through it. If there are similar regulatory concerns for the South Park Bridge, a tunnel or jack and bore may be required.

An alternative to tunneling would be providing separate electrical services and emergency generators, and using radio modems for controls. This has been done successfully on the Main Street Bridge in Green Bay, Wisconsin and will be implemented on the Hood Canal Bridge during the planned East Half Replacement Project.

The method chosen for getting power and control from one side of the bridge to the other would have some, but not significant, impact on the cost of rehabilitating the bridge's electrical systems.

The economic life of the electrical equipment is approximately 30 to 40 years. For a targeted 70-year bridge service life, at least one complete replacement of the entire electrical system would be expected following the initial rehabilitation of the bridge.

Preservation of Historical Architectural Features

As described in the above sections detailing proposed rehabilitation for Option 1, existing materials would be repaired, if feasible, or other wise replaced. Key features defining the historical character of the existing South Park Bridge include the lampposts and balustrades (railings) along the outside edge of the existing bridge. These features would be refurbished and/or repaired, or if necessary, reproduced to maintain the bridge's architectural look. Continuing deterioration of the old structure, however, would require on-going maintenance to preserve the historic character of the structure. Moreover, the service life of these elements of the bridge is uncertain. As such, this repair and maintenance work on these elements of the bridge would likely be considerable to ensure preservation of the historic character of the existing bridge.

Rehabilitation Option 2

The goal of this rehabilitation option is to provide a rehabilitated structure that would have a relatively predictable long-term service life. Because several major existing structural components are in a deteriorated condition and the existing concrete properties cannot be reliably assessed, this option proposes that some of the major components would be replaced. This approach would result in temporary removal of the bascule leaves and bridge closure for the duration of the construction period.

Compared to Option 1, the two most significant differences under Rehabilitation Option 2 are:

- The substructure and foundations of the bascule piers and truss approach piers would be replaced.
- The bascule leaves and approach trusses would be temporarily removed, refurbished and reinstalled during the construction.

The findings and proposed rehabilitation approach for Option 2 follow.

Bascule Foundations

New bascule pier foundations would be built within the footprint of the existing bascule pier foundations. Cofferdams would be required for the construction of the new pile caps. Dewatering would be required for pile cap construction, and coring through the existing tremie seal and timbers to install new, higher-capacity piles. See Figure 17.

Bascule Piers

For Option 2, the existing bascule piers would be entirely replaced with new piers. New pilings, foundations, and columns would be constructed in the same location as the existing piers. The dimensions of the new piers would be the same as the existing piers to preserve the historical character of the bridge.

Before demolition, careful cataloging and photographing of the existing piers would be conducted. This information would provide guidance to reconstruction of the bascule piers to preserve the architectural look and feel of the piers. The operator's house would be reproduced through finish work on the concrete or the addition of fascia panels to resemble current materials. Similar roof tiles and window mullions would be used to maintain the operator's house's current look. See Figure 18.

This approach to rehabilitation also provides opportunities to slightly modify the exterior look of the operator's house due to the use of all new materials. For example, a new window could be added to the operator's house to improve ventilation in the structure (see Figure 19). Consideration of such modifications, however, should be evaluated for consistency with federal guidelines for historic preservation. In addition, compliance with the Americans with Disabilities Act should be considered.

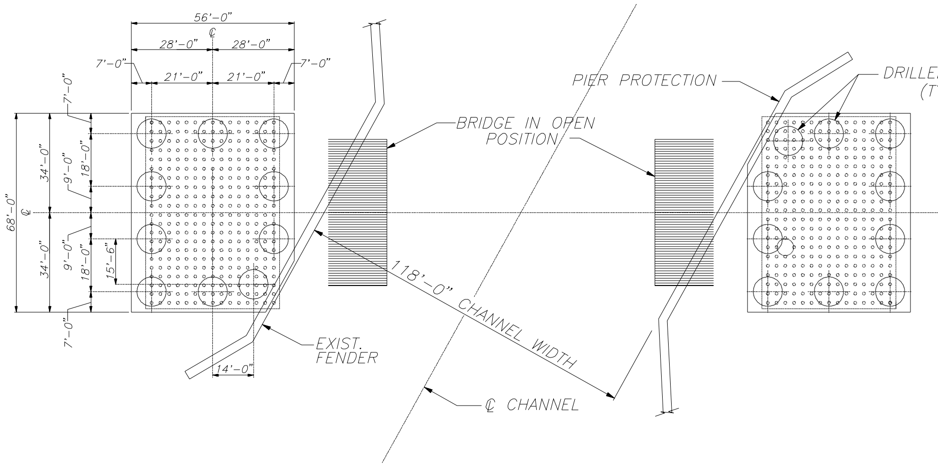

Figure 17: Bascule Pier Foundation – Rehabilitation Option 2

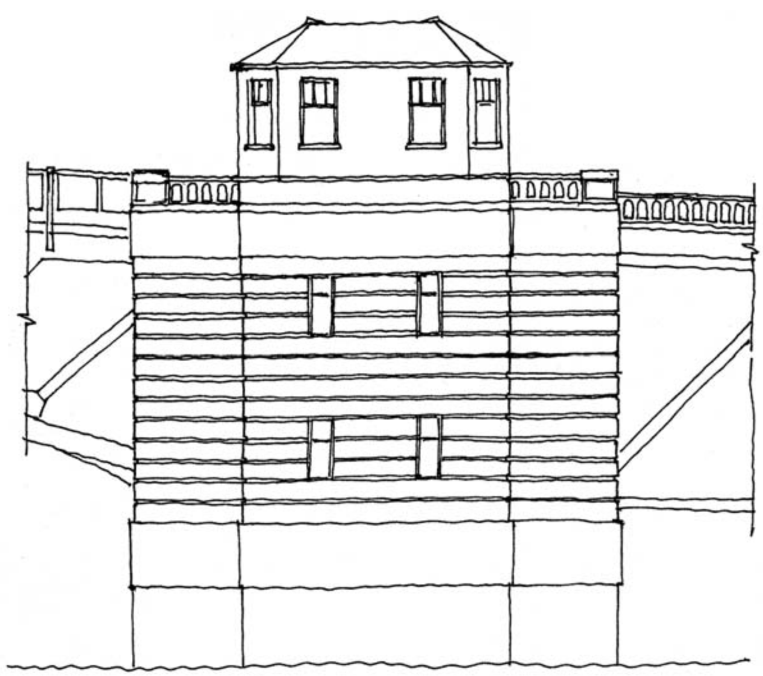

Figure 18: Existing Operator's House Profile
(as shown on the 1929 bridge drawings)

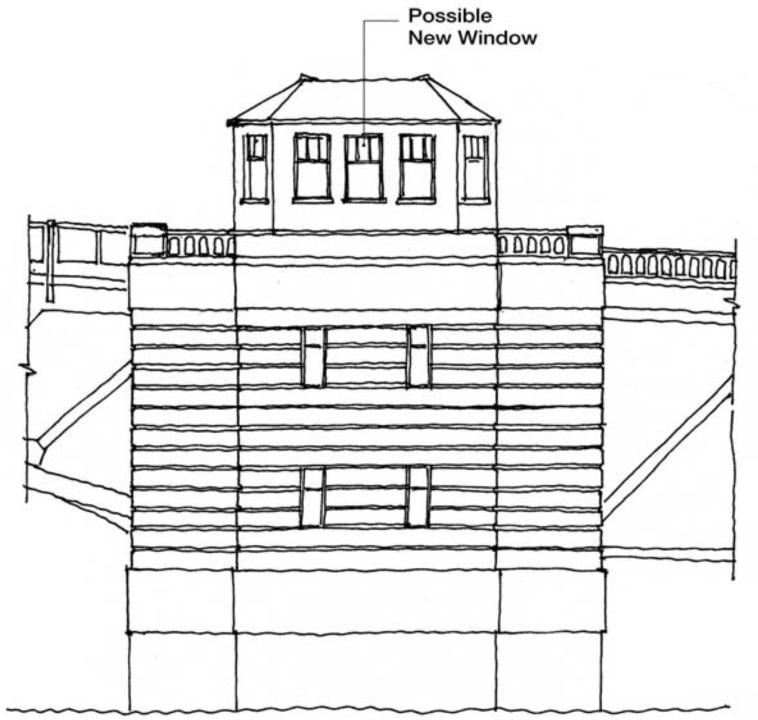

Figure 19: Suggested Operator's House Profile – Rehabilitation Option 2 (with new window to the operator's house)

Bascule Leaves (Truss Superstructure and Deck)

Because the superstructure is in adequate condition (per inspection reports), it is envisioned that the truss superstructure would be reconditioned, painted and re-used. After thorough cleaning, it may be determined that some of the truss members are too deteriorated to re-use, but they should be either strengthened or replaced with new, similar members. This is the same as proposed for Option 1.

The economical re-use of bascule leaves has been accomplished previously on other projects, including the Royal Park temporary bascule bridge in West Palm Beach, Florida. The bascule leaves would be disassembled in cantilever sections, which would be lifted and barged to another site for re-conditioning. As the leaves are disassembled, the counterweight would be supported in place, diamond saw-cut in place, and disassembled as the cantilevered sections are removed.

The rehabilitation activities recommended in the 2001 Imbsen Report [Ref. 1] would also be implemented. Section 6.1.1 of this report recommends adding new double angles to the frame laterals. Some vertical members of the truss should be replaced with large size members. In addition, a wide flange beam should be added to the bottom chord of the truss. These improvements would improve the lateral load path between the deck level and the bearing of the bascule span.

Steel Truss Approach Substructure (Piers and Foundations)

Because the bascule pier supports half of an approach truss span, removal of the steel truss approaches at the same time is recommended. Building a new substructure and foundations for the steel approach trusses that would be similar to the existing structures is also recommended. See Figure 20.

Steel Truss Approach Superstructure (Truss and Deck)

The steel approach span trusses appear to be in adequate condition. The *WSBIS Bridge Inspection Report* shows that the condition of the superstructure is in fair condition (the 2002 rating is 5.0 out of 8.0) [Refs. 19, 27]. The trusses would be cleaned, painted, and re-used. Since the trusses would be removed, it would be possible to transport them to a facility where they should be painted, resulting in better quality control and cheaper lead containment. If the condition of individual truss members is too far deteriorated, they should be either strengthened or replaced with new, similar members. This is the same as proposed for Option 1.

A previous study found that the "steel trusses are inadequately restrained and the pile foundations are inadequate" (regarding the vertical loads and seismically induced lateral loads) [Ref. 5]. The Imbsen Report [Ref. 1} found that "the steel truss approaches do not have a complete lateral load path to transfer lateral seismic loads from the deck level to the supports at the bascule pier". The recommended seismic restraint features in the Imbsen Report (Section 6.1.3, Truss Approach Span Superstructure) would be implemented. The seismic restraint features would consist of "one braced frame installed on each side of the pier to brace the truss, high-strength rod restrainers installed between Truss Approach 1 and Truss Approach 2, additional anchor bolts installed at the fixed support, a transverse shear key placed at the top of Pier 1, and a longitudinal slot in the new concrete block at the top of the pier to allow free longitudinal relative movement between the bottom strut and the concrete block." A similar shear key would be placed at the top of Pier 2. [Ref. 1]

Concrete Approach Structure

Because the bascule piers and foundations require replacement and bridge closure, replacement of the concrete approach structure and abutment pier walls should be implemented. Replacement of the existing structural elements with newly constructed elements that would have the same plan dimensions, and exterior surface materials and finishes would preserve the historic character of the existing bridge. See Figure 20.

It is structurally feasible, however, to improve on the structural strength of the concrete approach structures. Rather than using the existing design and general types of materials, voided pre-stressed slabs or WSDOT standard girders could be used. WSDOT standard girders with cast-in-place decks would be more durable than pre-cast concrete slabs. In addition, use of WSDOT W42G pre-cast pre-stressed girders would allow construction of a 60-foot span length, thus reducing the original twelve-span approach structure to a four-span new structure. See Figure 20. The increase in span length would decrease the number of piers and foundations that would need to be constructed, keeping costs down. Historic preservation regulations, however, would need to be weighed against these structural engineering and environmental impact considerations.

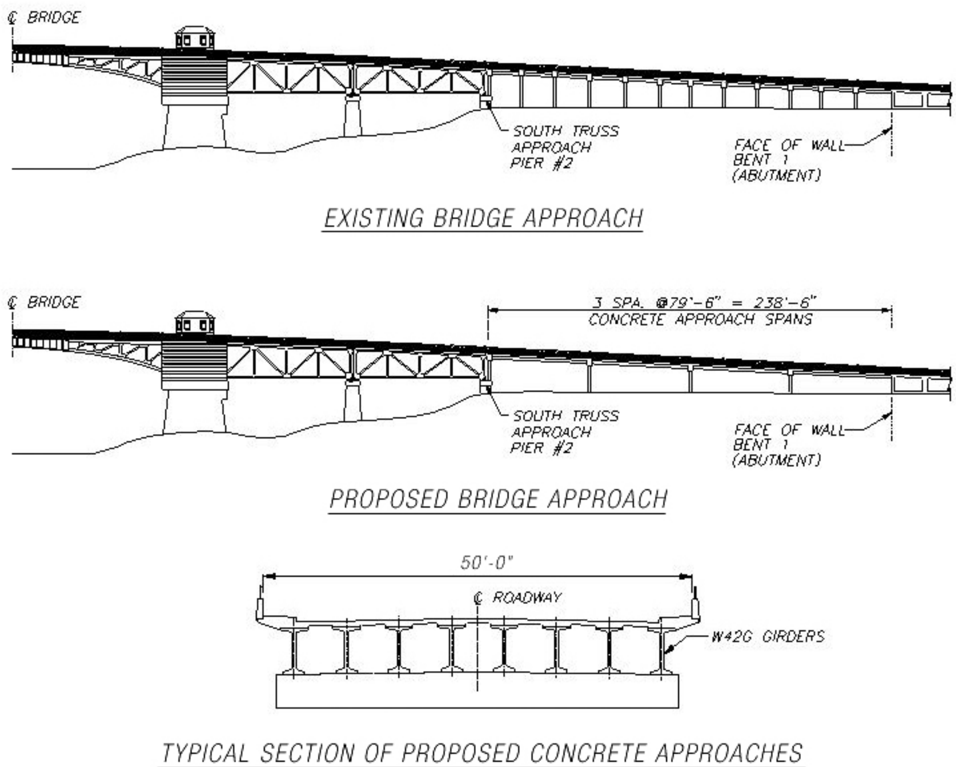

Figure 20
Concrete Approach Spans - Rehabilitation Option 2

Soil Improvement

To avoid potentially expensive problems due to liquefaction, an Earthquake Drain System is also proposed as a soil improvement along both sides of the bridge foundation as described for Option 1. The earthquake drain systems should be applied to an area of approximately 40 feet to either side of the existing footing of the structure.

Retaining Walls

Retaining walls along the south and north approaches were rotated and cracked during the Nisqually Earthquake. For this option, the retaining walls would be replaced, not repaired. Design and materials would be very similar to the existing structure to preserve the historic character of the bridge.

Mechanical System

The recommendation is to replace the existing machinery with new modern-design enclosed drives (approximately 35-year life). Thus, as discussed previously, the targeted 70-year service life requirement would necessitate replacement of modern machinery once in the life of the bridge. This is described in detail for Option 1.

Electrical System

The recommended electrical power and control system would be the same as described for Option 1. The approach would result in the replacement of the power and control system to comply with the National Electric Code. Like Option 1, this proposed replacement would provide an opportunity to improve the interior layout of the operator's house. Consideration of this modification, however, should be evaluated for consistency with the historic character of the structure and federal guidelines for historic preservation.

Preservation of Historical Architectural Features

As described in the above sections detailing proposed rehabilitation for Option 2, many elements of the existing bridge, particularly the bascule piers, would be replaced, rather than repaired and refurbished. Key features defining the historical character of the existing South Park Bridge include the lampposts and balustrades (railings) along the outside edge of the existing bridge. Due to the proposed construction of new bascule piers, foundations for the steel approach trusses, and concrete approach structure for this rehabilitation option, the recommended rehabilitation should include installation of new lampposts and balustrades. Prior to demolition, these design elements of existing bridge should be fully documented. The location, dimensions, and materials should be careful cataloged and photographed. This information would provide guidance to reconstruction of the structural elements to preserve the architectural look and feel of the bridge. Because these structural elements would be newly constructed, little repair and maintenance would be required. Moreover, the service life of these elements would be approximately 70 years. (See Figures 21 through 23 for the architectural features to be preserved.)

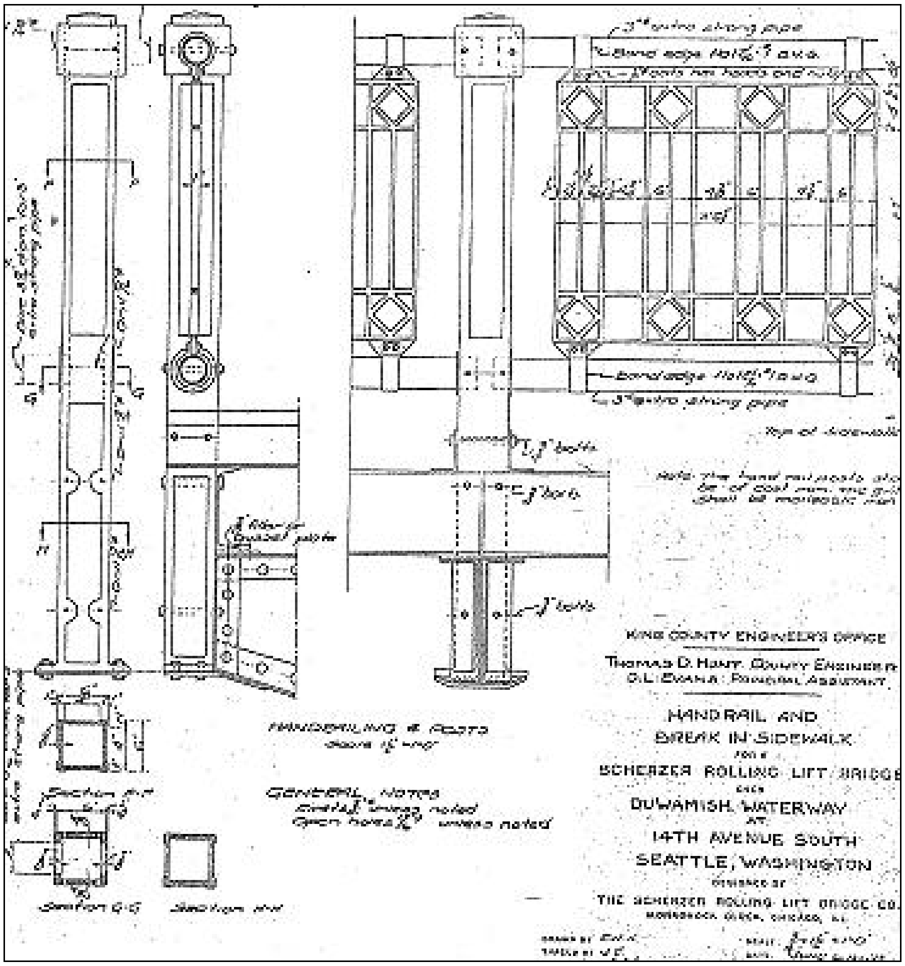

Figure 21: Original Drawings of Existing Metal Handrails

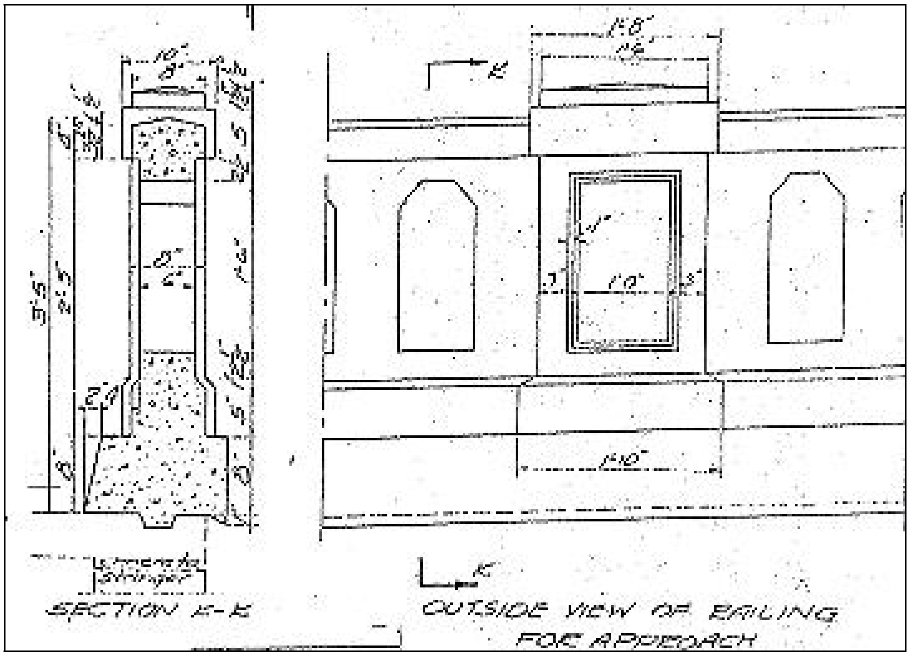

Figure 22: Original Drawings of Existing Concrete Handrails

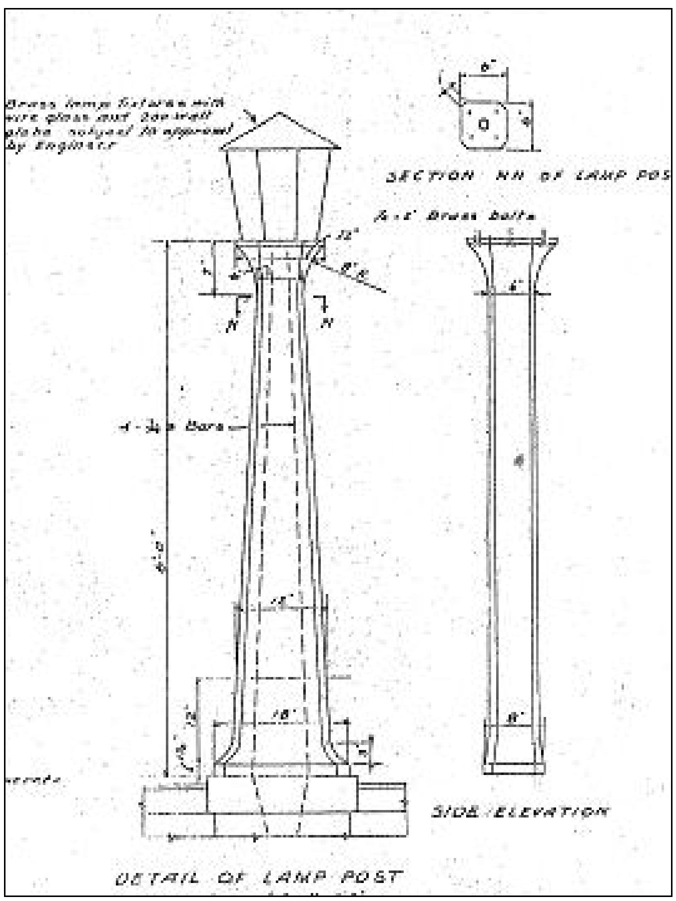

Figure 23: Original Drawings of Existing Lamp Posts

4. CONCEPTUAL COST ESTIMATES

This section discusses the conceptual cost estimates prepared for both rehabilitation options described in this feasibility study. The approach to these cost estimates as well as the assumptions incorporated in the cost estimates are outlined below. The detailed conceptual cost estimates for Option 1 and Option 2 are contained in Appendix B. Summaries of these cost estimates are shown in Table 1.

Approach

The conceptual cost estimates for Option 1 and Option 2 are based on the descriptions of proposed construction methods and the replacement or repair/refurbishment of the bridge described in the previous chapter. The conceptual cost estimates include structural, mechanical, and electrical costs as well as other related construction costs, including PS & E design. No operation or maintenance costs are included.

The construction costs are estimated for each major element of the bridge. Estimated cost items are provided for the following:

- Removal of existing structures, if necessary
- Bascule spans
- Steel truss approach spans
- Concrete approach spans
- Deck repair or reconstruction
- Soil improvement
- Retaining walls
- Bascule pier protection
- Electrical and mechanical
- Temporary construction platform
- Utilities (temporary or permanent relocation, new utilities)
- Disposal of contaminated wastes

Other costs include traffic maintenance during construction, the construction staging areas, environmental mitigation, design contingency, and mobilization. Construction contingency costs, support/administration, PS & E design, and right-of-way acquisition are also included in the conceptual rehabilitation cost estimates for Option 1 and Option 2.

Cost Assumptions

The construction cost estimates are based on the approximate quantities of materials determined from the conceptual designs for the two rehabilitation options. Unit costs for quantities of materials are based on figures listed in the *Washington State Department of Transportation, Bridge Design Manual, Section 12.3-A1-1 "Bridge and Structures Estimating Aids."* and published WSDOT bid tabulations of recent projects. These unit costs for structural elements of the bridge rehabilitation include costs associated with the cost of materials as well as labor. The costs are based on 2003 dollars. However, the costs associated with work previously recommended by Imbsen and Associates [Ref. 1] and incorporated into the conceptual design of either Option 1 or Option 2 were included in the conceptual cost estimate. Unit costs, however, were increased to adjust for inflation over the past two years.

For this conceptual study, the other related costs are mostly calculated as a percentage of cost estimate subtotals. For example, construction staging (2 percent), environmental mitigation (2 percent), and contingency during design are calculated as a percent of the construction estimated items. The cost of testing and disposal of contaminated waste is a rough estimate, based on very limited soil information available at this time. This cost will need be updated when additional soil information is available.

Estimated Life Cycle Costs

Comprehensive evaluation of the costs associated with Option 1 and Option 2, however, must also examine the likely costs associated with the long-term operation and maintenance of the two rehabilitation options. As described above, the conceptual design for the two options address needed repair and replacement for a 70-year service life of the structure. This assumption ensures comparison of like proposals for rehabilitation of the South Park Bridge.

Both options are for a bascule bridge and, as such, the operation costs would be expected to be very similar. The estimated operation costs is comprised primarily of the labor of bridge operator(s). As the bridge is currently open 24 hours a day and seven days a week, several full-time employees would be required to fully operate the bridge year-around.

The long-term maintenance costs associated with the two rehabilitation options for the South Park Bridge would be different. Replacement of the bridge's electrical and mechanical components is assumed for both options, so the long-term costs associated with maintenance of these components should be the similar. However, the long-term repair and maintenance costs associated with the bridge structure would differ. Option 2 encompasses replacing major structural elements of the bridge, whereas many of these same elements would be repaired and refurbished for Option 1. Routine maintenance such as cleaning and painting would be predictable and nearly the same for both options. However, maintenance costs for Option 1 would also include potentially unpredictable repair and maintenance, due to more extensive reliance on using the existing structures than in Option 2. This is especially true for concrete repairs and given the fact that the over 73-year-old concrete has ASR. Therefore, maintenance costs associated with Option 2 would be less than for Option 1.

Calculations for operation and maintenance of the two rehabilitation options under consideration in this study have been prepared as part of life cycle cost analysis. The estimated life cycle costs are included in Table 1 and in the Appendix.

Life cycle cost analyses were performed on the two rehabilitation options. The present value of the life cycle costs were calculated based on estimated construction costs, maintenance and operation costs, and environmental mitigation costs. The life cycle costs were not calculated based on other economic impacts, such as potential tax revenue changes or costs assigned to traffic delays. The following assumptions were used in the life cycle cost analyses:

- The bridge life cycle for this evaluation is assumed to be 70 years
- The projected inflation rate is assumed to be 3%
- The real discount rate is assumed to be 4%
- The nominal discount rate is assumed to be 7.12%

Summary of Conceptual Cost Estimates

This study included the preparation of conceptual costs estimates and life cycle cost estimates for the two rehabilitation options under consideration in this feasibility study. These cost estimates include individual cost estimates for the major structural elements of the options based on the conceptual engineering designs described in the previous chapter. The cost estimates also include estimates for electrical and mechanical work associated with construction, operation and maintenance costs during the expected bridge service life, and related construction costs (right-of-way acquisition, mobilization, staging, hazardous materials disposal, and environmental mitigation). Construction administration, PS&E design, and contingencies are also included in the total estimated project costs for the two options.

Analysis of the conceptual cost estimates concludes that the estimated total project cost for Options 1 and 2 are in the same magnitude..

Summaries of these conceptual cost estimates, including life cycle cost estimates, are shown in Table 1. Detailed information on these conceptual cost estimates is included in Appendix B.

TABLE 1
Conceptual Cost Estimates for Rehabilitation Options 1 and 2

ITEM		Option 1	Option 2
Construction Cost			
Structural	**$**	**21,969,000**	**$24,536,000**
Removal of Existing Structures	*$*	*1,999,000*	*$1,999,000*
Bascule Spans	*$*	*11,555,000*	*$9,426,000*
Steel Truss Approach Spans	*$*	*2,790,000*	*$2,689,000*
Concrete Approach Spans	*$*	*269,000*	*$2,872,000*
Retaining Walls	*$*	*154,000*	*$165,000*
Deck Reconstruction	*$*	*1,251,000*	*$1,435,000*
Soil Improvement	*$*	*1,000,000*	*$1,000,000*
Pier Protection	*$*	*1,500,000*	*$1,500,000*
Temporary Construction Platform	*$*	*1,200,000*	*$1,200,000*
Utilities	*$*	*250,000*	*$250,000*
Testing and Disposal of Contaminated Waste	*$*	*2,000,000*	*$2,000,000*
Mechanical & Electrical	**$**	**2,455,000**	**$3,255,000**
Subtotal A (structural, mechanical and electrical)	**$**	**24,424,000**	**$27,791,000**
Detours/Maintenance and Traffic	**$**	**250,000**	**$250,000**
Construction Staging Area/Disruption of Boeing Operations (2% of Subtotal A)	**$**	**488,000**	**$556,000**
Environmental Mitigation (2% of Subtotal A)	**$**	**488,000**	**$556,000**
Construction Contingency Items During Design	**$**	**9,770,000**	**$6,948,000**
Subtotal B (Items above)	**$**	**35,420,000**	**$36,101,000**
Mobilization (10% of Subtotal B)	**$**	**3,542,000**	**$3,610,000**
Subtotal C (Items above)	**$**	**38,962,000**	**$39,711,000**
Construction Contingency (15% of Subtotal C)	**$**	**5,844,000**	**$5,957,000**
Subtotal D (Items above)	**$**	**44,806,000**	**$45,668,000**
Construction Support & Administration (18% of Subtotal D)	**$**	**8,065,000**	**$8,220,000**
PS&E Design (15% of Subtotal D)	**$**	**6,721,000**	**$6,850,000**
Right of Way	**$**	**754,000**	**$754,000**
PROJECT TOTAL (2003 Dollar)	**$**	**60,346,000**	**$61,492,000**
PRESENT VALUE OF LIFE CYCLE COST (2003 Dollar):	**$**	**72,037,000**	**$71,854,000**

5. REMAINING SERVICE LIFE

An important factor to consider in evaluating different rehabilitation options for the existing South Park Bridge is the possible remaining service life of the structure and its component elements after the proposed rehabilitation construction and repair is completed. The following sections summarize previous attempts to estimate the remaining service life of the existing bridge, historic appraisals of the bridge deterioration, and current opinions concerning bridge deterioration and future service life of the two rehabilitation options evaluated in this study.

Previous Attempts to Estimate the Remaining Service Life

Previous studies provide some rough predictions of the South Park Bridge's remaining service life. These predictions are quoted below.

> <u>16th Avenue South Bridge Investigation Engineering Report (Sverdrup, July 1987) [Ref. 3]</u>
>
> *"Assuming that bascule piers are capable of being strengthened, and that the maintenance, improvements and repairs recommended in this study are performed, we believe the 16th Avenue South Bridge can remain in useful service for another 30 years." This study predicted the bridge would be functional until 2017.*
>
> <u>14th/16th Avenue South Bridge Rehabilitation/Replacement Design Report (Sverdrup, November 1994) [Ref. 11]</u>
>
> *"The RBB [Rehabilitated Bascule Bridge] alternative assumes that the existing bascule bridge would undergo short-term repairs as needed to allow it to operate for approximately the next ten years while a major renovation occurs. By the end of the tenth year the bridge will have been renovated as required to sustain an additional 50-year service life. After 50 years, the bascule bridge will be taken out of service or replaced."*
>
> <u>Seismic Study of 14th Avenue South Bridge (Imbsen & Associates, Inc., August, 2001) [Ref. 1]</u>
>
> *"In this study, two levels of earthquakes are adopted for evaluation based on a 10% seismic risk assuming the bridge has 10 or 20 years of remaining service life. In addition, an earthquake level that has a 10% chance exceedance in 50 years is considered when alternative retrofit schemes are investigated." In this report, a seismic analysis based on a 190-year earthquake instead of a 475-year earthquake was performed. This analysis was based on reduced earthquake risk, and justified by assuming the bridge has only ten to twenty years of remaining service life.*

These variable predictions illustrate the uncertainty of estimating an existing structure's service life. For the South Park Bridge, the uncertainty of predicting its remaining service life may partly due to the unclear nature of the cause of the existing concrete deterioration.

Previous Findings on Possible Causes of Deterioration

Previous studies had contradicting findings on the possible major cause of concrete deterioration [Refs. 8, 18, 47, 48]. Testing reported by Echelon Engineering, Inc. in 1994 and 1997 suggested "the possibility of chloride induced corrosion as a potentially significant contributor to the deteriorative process affecting these structures" [Ref. 8] and stated that "all of the concrete samples are at a chloride concentration that can initiate corrosion of steel in concrete." Echelon's testing also found that "the results of the soluble sulfate ion concentration analysis show that as was the case in the 1994 study, sulfate attack does not factor into the overall deterioration of the structures" [Ref.18]. On the contrary, a memo from Han-Padron Associates to WSDOT dated March 15, 2001, indicated that:

> *"The physical evidence (i.e. underwater photos) shows large spalled areas underwater, with soft crumbling concrete on the exterior surfaces . . . particularly at the corners of the piers. This type of deterioration is indicative of classic chemical deterioration of the concrete mix, most likely sulfate attack, but also possibly attributable to alkali-silica reaction (ASR) or delayed ettringite formation (DEF). Further evidence suggested that the deterioration is not the result of reinforcing steel corrosion…"* [Refs. 47, 48]

Project Team Opinions on Remaining Service Life

The service life of similar types of bridges varies widely, because there are many factors that can impact a structure's life. In our opinion, these factors can be grouped into four categories:

1) Service environment (includes climate, waterway, ground water, soil, chemical exposure, seismic, etc.),
2) Loads (includes average daily traffic volume, average daily truck traffic volume, frequency of overload vehicles, etc.),
3) Original design and construction (includes the design and construction quality, factor of safety applied to the structure, quality of the construction material, etc.), and
4) The quality and frequency of maintenance.

It has been mentioned in previous sections that on-site inspections and previous maintenance repairs indicate that steel reinforcing in the piers is sparse and rusted, and that the concrete is severely deteriorated, cracked and spalled in several places.

The *Concrete Condition Survey* (1994) by Boss and Mayes [Ref. 6] in the American Concrete Institute Report, ACI 201.2R, *Guide to Durable Concrete,* Section 5.5 – Preservation of Concrete Containing Reactive Aggregates states that: "There are no known methods of adequately preserving existing concrete which contains the elements that contribute to the previously described chemical reactions . . . Hence, repairs may slow the expansive mechanism, but the reactions will not completely stop . . . new cementitious repair materials with high alkali paste could reactivate exposed rhyolite particles."

Based on the available information, we find that no studies conducted to date have reliably predicted the future properties of the existing concrete, and there are no methods available that can reliably predict the longevity of an existing bridge with deteriorating concrete condition. By using engineering judgment, we came to the following conclusions:

- For Rehabilitation Option 1, which would repair the bridge substructures, the service life after rehabilitation would be shorter than a rehabilitation program to replace the substructures. The exact duration of the remaining service life would vary depending on many factors, but mostly on the deterioration rate, as indicated by Professional Service Industries, Inc. (a material testing firm) in their *South Park Bridge Concrete Condition Survey* memo of January 10, 2003 [Ref. 49]. Moreover, another complete rehabilitation would likely need to occur in order to extend the service life of the bridge for a comparable approximate 70 years.
- For Rehabilitation Option 2, which would replace the bridge substructures, our judgment is that this option would extend the bridge's service life by approximately 70 years or more.

6. COMPARISONS AND RECOMMENDATION

This section compares the advantages and disadvantages of the two rehabilitation options and proposes a final recommendation for the proposed rehabilitation of the South Park Bridge.

Comparison of the Rehabilitation Options

Rehabilitation Option 1

(rehabilitate most of the existing substructure by adding supplemental structure)

Advantages

The existing bridge could be open to vehicular traffic during part of the substructure construction period, avoiding complete closure during the entire construction period (as in Option 2).

Disadvantages

- The additional substructure required to strengthen the approach structures would add more columns and footings in the river.
- The existing structure's historical appearance would be significantly altered by the addition of structural members used to strengthen the steel truss approach piers and bascule piers.
- Rehabilitation would require the use of difficult and higher-risk construction methods (i.e., drilling through existing pile caps, and the potential differential settlement of the existing footing during construction).
- The uncertain existing condition of the substructure concrete and footings would result in a less predictable remaining service life.

Rehabilitation Option 2

(replace bascule piers, approach piers, and concrete approaches and rehabilitate steel trusses)

Advantages

- The reconstructed bascule piers and steel truss approach piers would be nearly the same size as the existing structure footings in the river.
- The existing bridge's historical appearance would be mostly preserved.
- The remaining service life would be relatively predictable compared to Option 1.

Disadvantages

- Significant construction impacts on vehicle, bicycle, and pedestrian traffic and the South Park community because the bridge would be closed for rehabilitation for up to three years.

These comparisons between the two rehabilitation options are summarized in Table 2 below. A plus sign (+) indicates that one option is relatively better than the other, and a negative sign (-) indicates that it is relatively worse. The estimated costs to construct these two options are similar. It is important to keep in mind that both rehabilitation options would provide only three traffic lanes, compared to four traffic lanes that could be incorporated into other possible structural solutions.

TABLE 2
Comparison of Rehabilitation Options

Comparison Items	Option 1	Option 2
Construction Impact on Land Traffic	+	-
Impact on Water Way Navigation Clearance	-	+
Impact on Historical Appearance	-	+
Remaining Service Life of the Structure	-	+
Construction Cost	Same	Same

Recommendation

The previous comparisons indicate that except for the disadvantage of having a longer construction impact on land traffic, Option 2 compares equally or more favorably than Option 1 in all comparison categories. Option 2 would provide a wider waterway clearance for navigation and would have a more predictable remaining service life. From the historical preservation point of view, Option 2would provide an opportunity to rebuild the structure and preserve the same appearance as the existing bridge, but Option 1 would require significantly altering the existing appearance. Although Option 1 would "preserve" the existing bascule piers and footings, it is important to consider the unfavorable comparisons listed above. Considering that Option 1 would significantly change the bridge's existing appearance, the questions to consider is whether it would be worth paying the estimated high cost to preserve the deteriorated concrete. In our opinion, Option 1 is not a good choice unless it is absolutely necessary to preserve the deteriorated substructure concrete material at the existing location.

Based on this conclusion, PB recommends Rehabilitation Option 2 as the proposed Rehabilitation Alternative for environmental review in the South Park Bridge Project EIS. Option 2 should also be further evaluated and compared with the three other structural alternatives being considered for this bridge, including: (1) replacement with a new bascule bridge on a new alignment, (2) replacement with a new mid-level fixed bridge on a new alignment, and (3) replacement with a new high-level fixed bridge on a new alignment.

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APPENDIX A
SOUTH PARK BRIDGE AS-BUILT DRAWING INDEX

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Bascule Piers	103-11D	9587
Bascule Pier and Operators House	103-11E	9589
Bascule Pier and Operators House	103-11F	9590
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Bascule Span ~ Timber Floor and Stringers	103-11H	9592
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Bascule Span ~ Floor Beams and Bracing	103-11J	9594
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Bascule Girders ~ Pts. 4 to 6	103-11L	9596
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APPENDIX B
CONCEPTUAL COST ESTIMATES FOR REHABILITATION OPTIONS 1 AND 2

Table 1
Conceptual Cost Estimate - Rehabilitation Option One

ITEM		COST
Construction Cost		
Structural	**$**	**21,969,000**
Bascule Spans	***$***	***11,555,000***
Shafts and Footings	*$*	*7,911,000*
Pier Wall and Footing Confinement	*$*	*2,638,000*
Fascia Wall Braced Frame	*$*	*177,000*
Seismic Upgrade of Bascule Leaves	*$*	*229,000*
Steel Truss Painting and Reconditioning	*$*	*600,000*
Steel Truss Approach Spans	***$***	***2,790,000***
Shafts	*$*	*1,144,000*
Columns and Pier Caps	*$*	*619,000*
Seismic Upgrade	*$*	*167,000*
Steel Truss Painting and Reconditioning	*$*	*800,000*
Expansion Joint Modification	*$*	*60,000*
Concrete Approach Spans	***$***	***269,000***
Seismic Upgrade	*$*	*239,000*
Expansion Joint Modification	*$*	*30,000*
Retaining Wall Rehabilitation	***$***	***154,000***
Deck Repair including Removal	***$***	***1,251,000***
Deck Repair	*$*	*1,186,000*
Traffic Barriers and Bridge Rails	*$*	*65,000*
Soil Improvement	***$***	***1,000,000***
Pier Protection	***$***	***1,500,000***
Temporary Construction Platform	***$***	***1,200,000***
Utilities	***$***	***250,000***
Testing and Disposal of Contaminated Waste	***$***	***2,000,000***
Mechanical & Electrical	**$**	**2,455,000**
Electrical	***$***	***1,255,000***
Mechanical	***$***	***1,200,000***
Subtotal A (structural, mechanical and electrical)	**$**	**24,424,000**
Detours/Maintenance and Traffic	**$**	**250,000**
Construction Staging Area/Disruption of Boeing Operations (2% of Subtotal A)	**$**	**488,000**
Environmental Mitigation (2% of Subtotal A)	**$**	**488,000**
Construction Contingency Items During Design (40% of Subtotal A)	**$**	**9,770,000**
Subtotal B (Items above)	**$**	**35,420,000**
Mobilization (10% of Subtotal B)	**$**	**3,542,000**
Subtotal C (Items above)	**$**	**38,962,000**
Construction Contingency (15% of Subtotal C)	**$**	**5,844,000**
Subtotal D (Items above)	**$**	**44,806,000**
Construction Support & Administration (18% of Subtotal D)	**$**	**8,065,000**
PS&E Design (15% of Subtotal D)	**$**	**6,721,000**
Right of Way	**$**	**754,000**
PROJECT TOTAL (2003 Dollar)	**$**	**60,346,000**
PRESENT VALUE OF LIFE CYCLE COST (2003 Dollar):	**$**	**72,037,000**

Table 1A
Conceptual Cost Estimate Details - Rehabilitation Option One

ITEM	UNIT MEASURE	QUANTITY		UNIT COST		COST
Construction Cost						
Structural						
Bascule Spans					$	11,555,000
Shafts and Footings					$	7,911,000
Soil Excavation For Footings Incl. Haul	CY	2917	$	50	$	145,833
Coffer Dam	SF	67,200	$	30	$	2,016,000
Soil Excavation For Shaft Incl. Haul (North Pier)	CY	2880	$	450	$	1,295,907
Soil Excavation For Shaft Incl. Haul (South Pier)	CY	1833	$	450	$	824,668
Furnishing & Placing Temp. Casing For 10 Ft Diam. Shaft (North Pier)	LF	990	$	200	$	198,000
Furnishing & Placing Temp. Casing For 10 Ft Diam. Shaft (South Pier)	LF	630	$	200	$	126,000
Furnishing Permanent Casing For 10 Ft Diam. Shaft (North Pier)	LF	90	$	350	$	31,500
Furnishing Permanent Casing For 10 Ft Diam. Shaft (South Pier)	LF	90	$	350	$	31,500
Placing Permanent Casing	EA	18	$	1,250	$	22,500
Conc. Class 4000p For Shaft	CY	4712	$	180	$	848,230
St. Reinf. Bar For Shaft (1.2%)	LB	748,797	$	0.50	$	374,398
Conc. Class 4000 For Footing	CY	3,833	$	400	$	1,533,333
St. Reinf. Bar For Footing (200 lbs per Cubic Yard)	LB	766,667	$	0.60	$	460,000
CSL Access Tube	LF	1,134	$	3.0	$	3,402
Pier Wall and Footing Confinement					$	2,638,000
8" Diameter Pipe	LB	2570	$	1.35	$	3,469
C15x33.9 Channel	LB	44070	$	1	$	44,070
1" THICK STEEL PLATE (for Channel arrangement)	LB	44200	$	2.50	$	110,500
C15x33.9 Channel	LB	32544	$	1	$	32,544
1" THICK STEEL PLATE (for Channel arrangement)	LB	32640	$	2.50	$	81,600
1-3/8" Diameter Pt Bars	LB	7156	$	2.50	$	17,889
1-3/8" Diameter Pt Bars	LB	11926	$	2.50	$	29,815
1-3/8" Diameter Pt Bars	LB	15012	$	2.50	$	37,530
1-3/8" Diameter Pt Bars	LB	18014	$	2.50	$	45,035
1-3/8" Diameter Pt Bars	LB	14345	$	2.50	$	35,863
1-3/8" Diameter Pt Bars	LB	19682	$	2.50	$	49,205
1-3/8" Diameter Pt Bars	LB	1001	$	2.50	$	2,503
1-3/8" Diameter Pt Bars	LB	3211	$	2.50	$	8,028
Drilling for PT Bar Installation	EA	728	$	1,000.00	$	728,000
12'-6" PT Tendon	LB	52416	$	2.50	$	131,040
12'-6" PT Tendon	LB	51300	$	2.50	$	128,250
1" THICK STEEL PLATE (for edges)	LB	114920	$	2.50	$	287,300
Concrete Channel and PT Covers	CY	345	$	287.00	$	99,015
Drilling for Tendon Duct Installation	EA	128	$	5,000.00	$	640,000
Concrete Blocks	CY	439	$	287.00	$	125,993
Fascia Wall Braced Frame					$	177,000
16 - WT9x225, 24' long	LB	9600	$	3.71	$	35,646
32 - 2L4x3x3/8, 7' long	LB	4070	$	3.71	$	15,113
32 - 2L4x3x3/8, 4' long	LB	2330	$	3.71	$	8,652
32 - L3x3x1/4, 5' long	LB	784	$	3.71	$	2,911
Connections	LB	3356	$	4.24	$	14,242
Interior Finishes for Control Tower	LS		$	100,000	$	100,000

Table 1A
Conceptual Cost Estimate Details - Rehabilitation Option One (continued)

Seismic Upgrade of Bascule Leaves					***$ 229,000***
Restrainers at Tracks and Counter Weights					$ 161,000
Track Restrainers	EA		$	19,096	$ 76,385
Counterweight Restrainers	EA		$	15,914	$ 63,654
Hydraulic Power Units	EA		$	5,305	$ 21,218
Add Angles to Top Laterals					$ 4,455
8-L3 1/2x3 1/2x1/2,11' long	LB	443	$	3.71	$ 3,628
Connections	LB	88	$	4.24	$ 828
Frame 0 New Members					$ 63,353
16 - 2L5x3 1/2 x3/4, 10' long	LB	2874	$	3.71	$ 23,527
2-W18x143, 36' long	LB	4670	$	3.18	$ 32,769
Connections	LB	754	$	4.24	$ 7,057
Steel Truss Painting and Reconditioning					***$ 600,000***
Steel Truss Painting and Reconditioning	LB				$ 600,000
Steel Truss Approach Spans					**$ 2,790,000**
Shafts					***$ 1,144,000***
Soil Excavation For Shaft Incl. Haul	CY	1396	$	450	$ 628,319
Furnishing & Placing Temp. Casing For 10 Ft Diam. Shaft	LF	480	$	200	$ 96,000
Furnishing Permanent Casing For 10 Ft Diam. Shaft	LF	120	$	350	$ 42,000
Placing Permanent Casing	EA	12	$	1,250	$ 15,000
Conc. Class 4000p For Shaft	CY	1396	$	180	$ 251,327
St. Reinf. Bar For Shaft (Assume ~1.2%)	LB	221,866	$	0.50	$ 110,933
CSL Access Tube (6 for each shaft)	LF	72	$	3.00	$ 216
Columns and Pier Caps					***$ 619,000***
Conc. Class 4000 For Columns (Pier 1)	CY	229	$	400	$ 91,595
Conc. Class 4000 For Columns (Pier 2)	CY	145	$	400	$ 58,085
St. Reinf. Bar For Columns (Use ~2%)	LB	74,325	$	0.60	$ 44,595
Conc. Class 4000 For Pier Caps	CY	676	$	400	$ 270,222
St. Reinf. Bar For Caps (300lbs/cy)	LB	202,667	$	0.60	$ 121,600
1-3/8" Diameter Pt Bars	LB	6761	$	2.50	$ 16,902
Drilling for PT Bar Installation	EA	16	$	1,000	$ 16,000
Seismic Upgrade					***$ 167,000***
Brace Frames @ Bascules					$ 90,732
8-WT12x38, 33' long	LB	10032	$	3.71	$ 37,250
24- 2L5x3 1/2x 3/4, 6.5' long	LB	6178	$	3.71	$ 22,940
24- 2L5x3 1/2x 3/4, 3.5' long	LB	3326	$	3.71	$ 12,350
24- L3x3x1/4, 3' long	LB	353	$	3.71	$ 1,311
Connections	LB	3978	$	4.24	$ 16,881
Anchor Bolts @ Fixed Supports					$ 849
16-1 1/2" diameter HS anchor bolts	EA	16	$	53	$ 849
Rod Restrainers					$ 356
8-1" diameter. 4' long HS rod restrainers	EA	8	$	45	$ 356
Transverse Shear Key					$ 24,666
4 ksi concrete	CY	40	$	530	$ 21,218
A706 reinforcement	LB	1760	$	0.95	$ 1,680
6-W12x22, 3' long & connections	LB	476	$	3.71	$ 1,767
Longitudinal Shear Key					$ 50,529
32 - 6'x1.5'x1/2 plates	LB	5880	$	3.71	$ 21,833
64 - 6'x6"x3/4" plates	LB	5880	$	3.18	$ 18,714
Connections	LB	2352	$	4.24	$ 9,981
Steel Truss Painting and Reconditioning					***$ 800,000***
Steel Truss Painting and Reconditioning	LB				$ 800,000
Expansion Joint Modification					***$ 60,000***
Expansion Joint Modification	LF	200	$	300	$ 60,000
Concrete Approach Spans					**$ 269,000**
Seismic Upgrade					***$ 239,000***
X Braces					$ 158,028
68-2 1/2' diameter, 28' long rod braces	LB	31797	$	2.65	$ 84,334
136 clevises	LB	3536	$	8.49	$ 30,011
68 turnbuckles	LB	1574	$	10.61	$ 16,699
Connections	LB	6359	$	4.24	$ 26,985
Rod Restrainers					$ 3,395
16-1" diameter, 20' long rod restrainers	EA	16	$	212	$ 3,395
Grade Beams					$ 77,974
34-20"x12", 20' long grade beams					
4 ksi concrete	CY	126	$	530	$ 66,837
Reinforcements	LB	2826	$	1	$ 2,826
Excavation	CY	332	$	25	$ 8,311

Table 1A
Conceptual Cost Estimate Details - Rehabilitation Option One (continued)

Expansion Joint Modification					***$***	***30,000***
Expansion Joint Modification	LF	100	$	300	$	30,000
Deck Repair including Removal					**$**	**1,251,000**
Deck Repair					***$***	***1,186,000***
Bridge Deck Repair	SY	6675	$	135	$	901,170
Sidewalk Repair	SY	2108	$	135	$	284,580
Traffic Barriers and Bridge Rails					***$***	***65,000***
Traffic Barriers and Bridge Rails to match historical	LF	1,294	$	50	$	64,700
Retaining Wall Rehabilitation					**$**	**154,000**
Retaining Wall Rehabilitation & Soil Stabilization	SF	5,635	$	25	$	140,880
ACP Pavement	SY	444	$	30	$	13,333
Soil Improvement					**$**	**1,000,000**
Earthquake Drain System	LS				$	1,000,000
Pier Protection					**$**	**1,500,000**
Pier Protection	EA		$	750,000	$	1,500,000
Temporary Construction Platform					**$**	**1,200,000**
	SF	1115	$	100	$	1,200,000
Utilities					**$**	**250,000**
	LS				$	250,000
Testing and Disposal of Contaminated Waste					**$**	**2,000,000**
	LS				$	2,000,000
Mechanical & Electrical						
Electrical					**$**	**1,255,000**
Electrical Service Entrance	LS		$	50,000	$	50,000
Motor Control Centers	EA		$	40,000	$	80,000
SCR Drives	EA		$	70,000	$	280,000
Bridge Control Desk and Panels	LS		$	225,000	$	225,000
Traffic Gates	EA		$	30,000	$	120,000
Traffic Signals	EA		$	25,000	$	50,000
Submarine Cable	LS		$	200,000	$	200,000
House Lights and Receptacles	LS		$	25,000	$	25,000
Emergency Generator	LS		$	75,000	$	75,000
125 hp Shunt Wound DC Motors	EA		$	25,000	$	100,000
Illumination	LS		$	50,000	$	50,000
Mechanical					**$**	**1,200,000**
Rehab cost	LS				$	1,200,000

Subtotal A (structural, mechanical and electrical)	**$**	**24,424,000**
Detours/Maintenance and Traffic	$	250,000
Construction Staging Area/Disruption of Boeing Operations (2% of Subtotal A)	$	488,000
Environmental Mitigation (2% of Subtotal A)	$	488,000
Construction Contingency Items During Design (40% of Subtotal A)	$	9,770,000
Subtotal B (Items above)	**$**	**35,420,000**
Mobilization (10% of Subtotal B)	$	3,542,000
Subtotal C (Items above)	**$**	**38,962,000**
Construction Contingency (15% of Subtotal C)	$	5,844,000
Subtotal D (Items above)	**$**	**44,806,000**
Construction Support & Administration (18% of Subtotal D)	$	8,065,000
PS&E Design (15% of Subtotal D)	$	6,721,000
Right of Way	$	754,000
PROJECT TOTAL (2003 Dollar)	**$**	**60,346,000**

Table 1B
Life Cycle Cost Analysis - Rehabilitation Option One

Parameters for present value cost analysis

i =	*0.04*	*(Real discount rate)*
f =	*0.03*	*(Projected inflation rate)*
i_f =	0.0712	*(Nominal discount rate)*
n =	*70*	*years*

Conceptual Operation and Maintenance Costs - Rehabilitation Option One

ITEM	*UNIT MEASURE*	*QUANTITY*	*UNIT COST*	*COST (2003 dollars)*	
Operation and Maintenance					
Operating Cost					
Operation Supervisor (1 person, 20hrs/week)	*Hrs*	*1,040*	*$ 75*	*$ 78,000*	*per year*
Operators (168 hrs/week)	*Hrs*	*8,736*	*$ 28*	*$ 244,608*	*per year*
Maintenance Cost					
Maintenance, (4 person, 32 hrs/month)	*Hrs*	384	*$ 60*	*$ 23,040*	*per year*
Maintenance Materials & Utilities	*Months*	*12*	*$ 5,000*	*$ 60,000*	*per year*
Repainting Steel Members	*LB*	*1,920,000*	*$ 0.75*	*$ 1,440,000*	*every 20 years*
Repair LMC Wearing Surface	*SF*	*44,840*	*$ 15*	*$ 672,600*	*every 20 years*
Repair ACP Wearing Surface	*SY*	*929*	*$ 30*	*$ 27,867*	*every 10 years*
Monitoring Bridge Condition (including underwater inspection)	*Months*	*12*	*$ 2,000*	*$ 24,000*	*per year*
Replace Motor Control Centers	*EA*	*2*	$ 40,000	*$ 80,000*	*every 35 years*
Replace SCR Drives	*EA*	*4*	$ 70,000	*$ 280,000*	*every 35 years*
Replace 125 hp Shunt Wound DC Motors	*EA*	*4*	$ 25,000	*$ 100,000*	*every 35 years*
Replace Mechanical Parts	*EA*	*1*	*$ 400,000*	*$ 400,000*	*every 35 years*
Total Capital Cost				***$ 60,346,000***	
PRESENT VALUE OF LIFE CYCLE COST (2003 Dollar):				**$ 72,037,000**	

Periodic Costs

Year	Routine Maintenance	Operating Cost	Inspection	Painting	Wearing Surface	Mechanical & Electrical	Annual Total	Present Value
0	***Total Capital Cost***						$ 60,346,000	$ 60,346,000
1	$ 83,040	$ 322,608	$ 24,000				$ 429,648	$ 401,090
2	$ 85,531	$ 332,286	$ 24,720				$ 442,537	$ 385,664
3	$ 88,097	$ 342,255	$ 25,462				$ 455,814	$ 370,831
4	$ 90,740	$ 352,522	$ 26,225				$ 469,488	$ 356,568
5	$ 93,462	$ 363,098	$ 27,012				$ 483,573	$ 342,854
6	$ 96,266	$ 373,991	$ 27,823				$ 498,080	$ 329,667
7	$ 99,154	$ 385,211	$ 28,657				$ 513,022	$ 316,988
8	$ 102,129	$ 396,767	$ 29,517				$ 528,413	$ 304,796
9	$ 105,193	$ 408,670	$ 30,402				$ 544,265	$ 293,073
10	$ 108,348	$ 420,930	$ 31,315		$ 37,450		$ 598,044	$ 300,626
11	$ 111,599	$ 433,558	$ 32,254				$ 577,411	$ 270,962
12	$ 114,947	$ 446,565	$ 33,222				$ 594,733	$ 260,541
13	$ 118,395	$ 459,962	$ 34,218				$ 612,575	$ 250,520
14	$ 121,947	$ 473,761	$ 35,245				$ 630,953	$ 240,884
15	$ 125,605	$ 487,974	$ 36,302				$ 649,881	$ 231,620
16	$ 129,374	$ 502,613	$ 37,391				$ 669,378	$ 222,711
17	$ 133,255	$ 517,691	$ 38,513				$ 689,459	$ 214,145
18	$ 137,252	$ 533,222	$ 39,668				$ 710,143	$ 205,909
19	$ 141,370	$ 549,219	$ 40,858				$ 731,447	$ 197,989
20	$ 145,611	$ 565,695	$ 42,084	$ 2,600,800	$ 1,265,121		$ 4,619,311	$ 1,167,256
21	$ 149,979	$ 582,666	$ 43,347				$ 775,992	$ 183,052
22	$ 154,479	$ 600,146	$ 44,647				$ 799,272	$ 176,012
23	$ 159,113	$ 618,150	$ 45,986				$ 823,250	$ 169,242
24	$ 163,887	$ 636,695	$ 47,366				$ 847,947	$ 162,733
25	$ 168,803	$ 655,796	$ 48,787				$ 873,386	$ 156,474

Table 1B
Life Cycle Cost Analysis - Rehabilitation Option One (continued)

26	$ 173,867	$ 675,470	$ 50,251				$ 899,587	$ 150,456
27	$ 179,083	$ 695,734	$ 51,758				$ 926,575	$ 144,669
28	$ 184,456	$ 716,606	$ 53,311				$ 954,372	$ 139,105
29	$ 189,990	$ 738,104	$ 54,910				$ 983,004	$ 133,755
30	$ 195,689	$ 760,247	$ 56,558		$ 67,640		$ 1,080,133	$ 137,202
31	$ 201,560	$ 783,054	$ 58,254				$ 1,042,868	$ 123,664
32	$ 207,607	$ 806,546	$ 60,002				$ 1,074,155	$ 118,907
33	$ 213,835	$ 830,742	$ 61,802				$ 1,106,379	$ 114,334
34	$ 220,250	$ 855,665	$ 63,656				$ 1,139,571	$ 109,937
35	$ 226,857	$ 881,335	$ 65,566			$ 2,419,922	$ 3,593,679	$ 323,646
36	$ 233,663	$ 907,775	$ 67,533				$ 1,208,970	$ 101,643
37	$ 240,673	$ 935,008	$ 69,559				$ 1,245,239	$ 97,733
38	$ 247,893	$ 963,058	$ 71,645				$ 1,282,597	$ 93,974
39	$ 255,330	$ 991,950	$ 73,795				$ 1,321,075	$ 90,360
40	$ 262,990	$ 1,021,708	$ 76,009	$ 4,697,334	$ 2,284,949		$ 8,342,990	$ 532,720
41	$ 270,880	$ 1,052,359	$ 78,289				$ 1,401,528	$ 83,543
42	$ 279,006	$ 1,083,930	$ 80,638				$ 1,443,574	$ 80,330
43	$ 287,376	$ 1,116,448	$ 83,057				$ 1,486,881	$ 77,240
44	$ 295,997	$ 1,149,942	$ 85,548				$ 1,531,488	$ 74,269
45	$ 304,877	$ 1,184,440	$ 88,115				$ 1,577,432	$ 71,413
46	$ 314,024	$ 1,219,973	$ 90,758				$ 1,624,755	$ 68,666
47	$ 323,444	$ 1,256,572	$ 93,481				$ 1,673,498	$ 66,025
48	$ 333,148	$ 1,294,269	$ 96,285				$ 1,723,703	$ 63,486
49	$ 343,142	$ 1,333,098	$ 99,174				$ 1,775,414	$ 61,044
50	$ 353,436	$ 1,373,090	$ 102,149		$ 122,165		$ 1,950,841	$ 62,617
51	$ 364,040	$ 1,414,283	$ 105,214				$ 1,883,536	$ 56,438
52	$ 374,961	$ 1,456,712	$ 108,370				$ 1,940,043	$ 54,268
53	$ 386,210	$ 1,500,413	$ 111,621				$ 1,998,244	$ 52,181
54	$ 397,796	$ 1,545,425	$ 114,970				$ 2,058,191	$ 50,174
55	$ 409,730	$ 1,591,788	$ 118,419				$ 2,119,937	$ 48,244
56	$ 422,022	$ 1,639,542	$ 121,972				$ 2,183,535	$ 46,388
57	$ 434,682	$ 1,688,728	$ 125,631				$ 2,249,041	$ 44,604
58	$ 447,723	$ 1,739,390	$ 129,400				$ 2,316,512	$ 42,889
59	$ 461,154	$ 1,791,572	$ 133,282				$ 2,386,008	$ 41,239
60	$ 474,989	$ 1,845,319	$ 137,280	$ 8,483,908	$ 4,126,872		$ 15,068,368	$ 243,127
61	$ 489,239	$ 1,900,678	$ 141,398				$ 2,531,315	$ 38,128
62	$ 503,916	$ 1,957,699	$ 145,640				$ 2,607,255	$ 36,661
63	$ 519,033	$ 2,016,430	$ 150,010				$ 2,685,473	$ 35,251
64	$ 534,604	$ 2,076,922	$ 154,510				$ 2,766,037	$ 33,895
65	$ 550,642	$ 2,139,230	$ 159,145				$ 2,849,018	$ 32,592
66	$ 567,162	$ 2,203,407	$ 163,920				$ 2,934,488	$ 31,338
67	$ 584,177	$ 2,269,509	$ 168,837				$ 3,022,523	$ 30,133
68	$ 601,702	$ 2,337,595	$ 173,902				$ 3,113,199	$ 28,974
69	$ 619,753	$ 2,407,722	$ 179,119				$ 3,206,595	$ 27,860
70	$ 638,346	$ 2,479,954	$ 184,493		$ 220,643	$ 6,809,327	$ 10,332,763	$ 83,806
						TOTAL COST:		**$ 72,037,000**

Table 2
Conceptual Cost Estimate - Rehabilitation Option Two

ITEM		COST SUMMARY
Construction Cost		
Structural	**$**	**24,536,000**
Removal of Existing Structures	***$***	***1,999,000***
Bascule Spans	***$***	***9,426,000***
Shafts and Footings	*$*	*6,587,000*
Pier Substructure, Machine Room and Control House	*$*	*2,010,000*
Seismic Upgrade of Bascule Leaves	*$*	*229,000*
Bascule Leaf Refurbishing and Reinstallation	*$*	*600,000*
Steel Truss Approach Spans	***$***	***2,689,000***
Shafts	*$*	*763,000*
Columns and Pier Caps	*$*	*939,000*
Seismic Upgrade	*$*	*167,000*
Steel Truss Refurbishing and Reinstallation	*$*	*800,000*
Expansion Joint	*$*	*20,000*
Concrete Approaches	***$***	***2,872,000***
Shafts	*$*	*1,487,000*
Columns and Pier Caps	*$*	*1,113,000*
Superstructure	*$*	*272,000*
Approach Fill and Retaining Walls	***$***	***165,000***
Deck Reconstruction	***$***	***1,435,000***
Deck Reconstruction	*$*	*1,176,000*
Traffic Barriers and Bridge Rails	*$*	*259,000*
Soil Improvement	***$***	***1,000,000***
Pier Protection	***$***	***1,500,000***
Temporary Construction Platform	***$***	***1,200,000***
Utilities	***$***	***250,000***
Testing and Disposal of Contaminated Waste	***$***	***2,000,000***
Mechanical & Electrical	**$**	**3,255,000**
Electrical	**$**	**1,255,000**
Mechanical	**$**	**2,000,000**
Subtotal A (structural, mechanical and electrical)	**$**	**27,791,000**
Detours/Maintenance and Traffic	**$**	**250,000**
Construction Staging Area/Disruption of Boeing Operations (2% of Subtotal A)	**$**	**556,000**
Environmental Mitigation (2% of Subtotal A)	**$**	**556,000**
Construction Contingency Items During Design (25% of Subtotal A)	**$**	**6,948,000**
Subtotal B (Items above)	**$**	**36,101,000**
Mobilization (10% of Subtotal B)	**$**	**3,610,000**
Subtotal C (Items above)	**$**	**39,711,000**
Construction Contingency (15% of Subtotal C)	**$**	**5,957,000**
Subtotal D (Items above)	**$**	**45,668,000**
Construction Support & Administration (18% of Subtotal D)	**$**	**8,220,000**
PS&E Design (15% of Subtotal D)	**$**	**6,850,000**
Right of Way	**$**	**754,000**
PROJECT TOTAL (2003 Dollar)	**$**	**61,492,000**
PRESENT VALUE OF LIFE CYCLE COST (2003 Dollar):	**$**	**71,854,000**

Table 2A
Conceptual Cost Estimate Details - Rehabilitation Option Two

ITEM	UNIT MEASURE	QUANTITY	UNIT COST	COST
Construction Cost				
Structural				
Removal of Existing Structures				**$ 1,999,000**
Removal of Bascule Spans	SF	12,000	$ 50	$ 600,000
Removal of Steel Trusses from Truss Approach Spans	SF	16,900	$ 40	$ 676,000
Demolition of Concrete Approach Spans	SF	24,125	$ 25	$ 603,125
Demolition of Approach Fill and Retaining Walls	SF	12,000	$ 10	$ 120,000
Bascule Spans				**$ 9,426,000**
Shafts and Footings				***$ 6,587,000***
Soil Excavation For Footings Incl. Haul	CY	1,804	$ 50	$ 90,222
Coffer Dam	SF	46,080	$ 30	$ 1,382,400
Soil Excavation For Shaft Incl. Haul (North Pier)	CY	3,200	$ 450	$ 1,439,897
Soil Excavation For Shaft Incl. Haul (South Pier)	CY	2,036	$ 450	$ 916,298
Furnishing & Placing Temp. Casing For 10 Ft Diam. Shaft (North Pier)	LF	1,100	$ 200	$ 220,000
Furnishing & Placing Temp. Casing For 10 Ft Diam. Shaft (South Pier)	LF	700	$ 200	$ 140,000
Furnishing Permanent Casing For 10 Ft Diam. Shaft (North Pier)	LF	100	$ 350	$ 35,000
Placing Permanent Casing For 10 Ft Diam. Shaft (North Pier)	EA	10	$ 1,250	$ 12,500
Furnishing Permanent Casing For 10 Ft Diam. Shaft (South Pier)	LF	100	$ 350	$ 35,000
Placing Permanent Casing For 10 Ft Diam. Shaft (South Pier)	EA	10	$ 1,250	$ 12,500
Conc. Class 4000p For Shaft	CY	5,236	$ 180	$ 942,478
St. Reinf. Bar For Shaft (1.2%)	LB	831,996	$ 0.50	$ 415,998
Conc. Class 4000 For Footing	CY	1,692	$ 400	$ 676,978
St. Reinf. Bar For Footing (200 lbs per Cubic Yard)	LB	338,489	$ 0.60	$ 203,093
CSL Access Tube	LF	21,600	$ 3.0	$ 64,800
Pier Substructure, Machine Room and Control House				***$ 2,010,000***
Concrete Class 4000	CY	3,035	$ 400	$ 1,214,075
St. Reinf. Bar (300lbs/cy)	LB	910,556	$ 0.6	$ 546,334
FRP - Pier Caps and Control Houses	LS		$ 150,000	$ 150,000
Interior Finishes for Control Tower	LS		$ 100,000	$ 100,000
Seismic Upgrade of Bascule Leaves				**$ 229,000**
Restrainers at Tracks and Counter Weights				$ 161,000
Track Restrainers	EA		$ 19,096	$ 76,385
Counterweight Restrainers	EA		$ 15,914	$ 63,654
Hydraulic Power Units	EA		$ 5,305	$ 21,218
Add Angles to Top Laterals				$ 4,455
8-L3 1/2x3 1/2x1/2,11' long	LB	443	$ 3.71	$ 3,628
Connections	LB	88	$ 4.24	$ 828
Frame 0 New Members				$ 63,353
16 - 2L5x3 1/2 x3/4, 10' long	LB	2874	$ 3.71	$ 23,527
2-W18x143, 36' long	LB	4670	$ 3.18	$ 32,769
Connections	LB	754	$ 4.24	$ 7,057
Bascule Leaf Refurbishing and Reinstallation				***$ 600,000***
Bascule Leaf Refurbishing and Reinstallation	LB			$ 600,000

Table 2A
Conceptual Cost Estimate Details - Rehabilitation Option Two (continued)

Steel Truss Approach Spans					**$**	**2,689,000**
Shafts					***$***	***763,000***
Soil Excavation For Shaft Incl. Haul	CY	931	$	450	$	418,879
Furnishing & Placing Temp. Casing For 10 Ft Diam. Shaft	LF	320	$	200	$	64,000
Furnishing Permanent Casing For 10 Ft Diam. Shaft	LF	80	$	350	$	28,000
Placing Permanent Casing For 10 Ft Diam. Shaft	EA	8	$	1,250	$	10,000
Conc. Class 4000p For Shaft	CY	931	$	180	$	167,552
St. Reinf. Bar For Shaft (Assume ~1.2%)	LB	147,910	$	0.50	$	73,955
CSL Access Tube (6 for each shaft)	LF	48	$	3.00	$	144
Columns and Pier Caps					***$***	***939,000***
Conc. Class 4000 For 8' Columns (Pier 1)	CY	156	$	400	$	62,553
Conc. Class 4000 For 8' Columns (Pier 2)	CY	97	$	400	$	38,723
St. Reinf. Bar For Columns (Use ~2%)	LB	50,290	$	0.60	$	30,174
Conc. Class 4000 For Pier Caps	CY	1,351	$	400	$	540,444
St. Reinf. Bar For Caps (300lbs/cy)	LB	405,333	$	0.60	$	243,200
Bearing Replacement	EA	8	$	3,000	$	24,000
Seismic Upgrade					***$***	***167,000***
Brace Frames @ Bascules					$	90,732
8-WT12x38, 33' long	LB	10,032	$	3.71	$	37,250
24- 2L5x3 1/2x 3/4, 6.5' long	LB	6,178	$	3.71	$	22,940
24- 2L5x3 1/2x 3/4, 3.5' long	LB	3,326	$	3.71	$	12,350
24- L3x3x1/4, 3' long	LB	353	$	3.71	$	1,311
Connections	LB	3,978	$	4.24	$	16,881
Anchor Bolts @ Fixed Supports					$	849
16-1 1/2" diameter HS anchor bolts	each	16	$	53	$	849
Rod Restrainers					$	356
8-1" diameter. 4' long HS rod restrainers	each	8	$	45	$	356
Transverse Shear Key					$	24,666
4 ksi concrete	CY	40	$	530	$	21,218
A706 reinforcement	LB	1,760	$	0.95	$	1,680
6-W12x22, 3' long & connections	LB	476	$	3.71	$	1,767
Longitudinal Shear Key					$	50,529
32 - 6'x1.5'x1/2 plates	LB	5,880	$	3.71	$	21,833
64 - 6'x6"x3/4" plates	LB	5,880	$	3.18	$	18,714
Connections	LB	2,352	$	4.24	$	9,981
Steel Truss Refurbishing and Reinstallation					***$***	***800,000***
Steel Truss Removal and Reinstallation	LS				$	800,000
Expansion Joint					***$***	***20,000***
Expansion Joint	LF	200	$	100	$	20,000
Concrete Approaches					**$**	**2,872,000**
Shafts					***$***	***1,487,000***
Soil Excavation For 6' Shaft Incl. Haul	CY	2,513	$	250	$	628,319
Furnishing & Placing Temp. Casing For 8 Ft Diam. Shaft	LF	2,400	$	100	$	240,000
Furnishing Permanent Casing For 8 Ft Diam. Shaft	LF	480	$	200	$	96,000
Placing Permanent Casing For 8 Ft Diam. Shaft	EA	48	$	1,000	$	48,000
Conc. Class 4000p For Shaft	CY	2,513	$	125	$	314,159
St. Reinf. Bar For Shaft (Assume ~1.2%)	LB	399,358	$	0.40	$	159,743
CSL Access Tube (6 for each shaft)	LF	288	$	3.00	$	864
Columns and Pier Caps					***$***	***1,113,000***
Conc. Class 4000 For 4' Columns	CY	493	$	400	$	197,041
St. Reinf. Bar For Columns (Use ~2%)	LB	130,457	$	0.60	$	78,274
Conc. Class 4000 For Pier Caps	CY	1,444	$	400	$	577,778
St. Reinf. Bar For Caps (300lbs/cy)	LB	433,333	$	0.60	$	260,000
Superstructure					***$***	***272,000***
W42G Girders	LF	3,080	$	85	$	261,800
Expansion Joint	LF	100	$	100	$	10,000

Table 2A
Conceptual Cost Estimate Details - Rehabilitation Option Two (continued)

Approach Fill and Retaining Walls				**$ 165,000**
MSE Walls	SF	5,635	$ 20	$ 112,704
Approach Fill	CY	5,216	$ 10	$ 52,156
ACP Pavement	SY	444	$ 30	$ 13,333
Deck Reconstruction				**$ 1,435,000**
Deck Reconstruction				***$ 1,176,000***
Concrete Class 4000D	CY	1,636	$ 500	$ 817,901
St. Reinf. Bar, Epoxy Coated (160lbs/cy)	LB	261,728	$ 0.75	$ 196,296
St. Reinf. Bar (180lbs/cy)	LB	294,444	$ 0.55	$ 161,944
Traffic Barriers and Bridge Rails				***$ 259,000***
Traffic Barriers and Bridge Rails to match historical	LF	1,294	$ 200	$ 258,800
Soil Improvement				**$ 1,000,000**
Earthquake Drain System	LS		$ -	$ 1,000,000
Pier Protection				**$ 1,500,000**
Pier Protection	each		$ 750,000	$ 1,500,000
Temporary Construction Platform				**$ 1,200,000**
	SF	1115	$ 100	$ 1,200,000
Utilities				**$ 250,000**
	LS			$ 250,000
Testing and Disposal of Contaminated Waste				**$ 2,000,000**
	LS			$ 2,000,000
Mechanical & Electrical				
Electrical				***$ 1,255,000***
Electrical Service Entrance	LS		$ 50,000	$ 50,000
Motor Control Centers	EA		$ 40,000	$ 80,000
SCR Drives	EA		$ 70,000	$ 280,000
Bridge Control Desk and Panels	LS		$ 225,000	$ 225,000
Traffic Gates	EA		$ 30,000	$ 120,000
Traffic Signals	EA		$ 25,000	$ 50,000
Submarine Cable	LS		$ 200,000	$ 200,000
House Lights and Receptacles	LS		$ 25,000	$ 25,000
Emergency Generator	LS		$ 75,000	$ 75,000
125 hp Shunt Wound DC Motors	EA		$ 25,000	$ 100,000
Illumination	LS		$ 50,000	$ 50,000
Mechanical				***$ 2,000,000***
Rehab cost	LS			$ 2,000,000

Subtotal A (structural, mechanical and electrical)	**$ 27,791,000**
Detours/Maintenance and Traffic	$ 250,000
Construction Staging Area/Disruption of Boeing Operations (2% of Subtotal A)	$ 556,000
Environmental Mitigation (2% of Subtotal A)	$ 556,000
Construction Contingency Items During Design (25% of Subtotal A)	$ 6,948,000
Subtotal B (Items above)	**$ 36,101,000**
Mobilization (10% of Subtotal B)	$ 3,610,000
Subtotal C (Items above)	**$ 39,711,000**
Construction Contingency (15% of Subtotal C)	$ 5,957,000
Subtotal D (Items above)	**$ 45,668,000**
Construction Support & Administration (18% of Subtotal D)	$ 8,220,000
PS&E Design (15% of Subtotal D)	$ 6,850,000
Right of Way	$ 754,000
PROJECT TOTAL (2003 Dollar)	**$ 61,492,000**

Table 2B
Life Cycle Cost Analysis - Rehabilitation Option Two

Parameters for present value cost analysis

i =	*0.04*	*(Real discount rate)*
f =	*0.03*	*(Projected inflation rate)*
i_f =	0.0712	*(Nominal discount rate)*
n =	*70*	*years*

Conceptual Operation and Maintenance Cost

ITEM	UNIT MEASURE	QUANTITY	UNIT COST	COST (2003 dollars)	
Operation and Maintenance					
Operating Cost					
Operation Supervisor (1 person, 20hrs/week)	*Hrs*	*1,040*	*$ 75.00*	*$ 78,000*	*per year*
Operators (168 hrs/week)	*Hrs*	*8,736*	*$ 28.00*	*$ 244,608*	*per year*
Maintenance Cost					
Maintenance, (2 person, 16 hrs/month)	*Hrs*	*192*	*$ 60.00*	*$ 11,520*	*per year*
Maintenance Materials & Utilities	*Months*	*12*	*$ 3,000.00*	*$ 36,000*	*per year*
Repainting Steel Members	*LB*	*1,920,000*	*$ 0.75*	*$ 1,440,000*	*every 20 years*
Repair LMC Wearing Surface	*SF*	*44,840*	*$ 15.00*	*$ 672,600*	*every 20 years*
Repair ACP Wearing Surface	*SY*	*929*	*$ 30.00*	*$ 27,867*	*every 10 years*
Routine Inspection				*$ 2,000*	*every 2 years*
Replace Motor Control Centers	*EA*	*2*	$ 40,000	*$ 80,000*	*every 35 years*
Replace SCR Drives	*EA*	*4*	$ 70,000	*$ 280,000*	*every 35 years*
Replace 125 hp Shunt Wound DC Motors	*EA*	*4*	$ 25,000	*$ 100,000*	*every 35 years*
Replace Mechanical Parts	*EA*	*1*	*$ 400,000*	*$ 400,000*	*every 35 years*
Total Capital Cost				***$ 61,492,000***	
PRESENT VALUE OF LIFE CYCLE COST (2003 Dollar):				**$ 71,854,000**	

Periodic Costs

Year	Routine Maintenance	Operating Cost	Inspection	Painting	Wearing Surface	Mechanical & Electrical	Annual Total	Present Value
0	***Total Capital Cost***						$ 61,492,000	$ 61,492,000
1	$ 47,520	$ 322,608					$ 370,128	$ 345,527
2	$ 48,946	$ 332,286	$ 2,060				$ 383,292	$ 334,032
3	$ 50,414	$ 342,255					$ 392,669	$ 319,459
4	$ 51,926	$ 352,522	$ 2,185				$ 406,634	$ 308,832
5	$ 53,484	$ 363,098					$ 416,582	$ 295,358
6	$ 55,089	$ 373,991	$ 2,319				$ 431,398	$ 285,532
7	$ 56,741	$ 385,211					$ 441,952	$ 273,075
8	$ 58,444	$ 396,767	$ 2,460				$ 457,671	$ 263,991
9	$ 60,197	$ 408,670					$ 468,867	$ 252,473
10	$ 62,003	$ 420,930	$ 2,610		$ 37,450		$ 522,993	$ 262,900
11	$ 63,863	$ 433,558					$ 497,421	$ 233,425
12	$ 65,779	$ 446,565	$ 2,768				$ 515,112	$ 225,660
13	$ 67,752	$ 459,962					$ 527,714	$ 215,815
14	$ 69,785	$ 473,761	$ 2,937				$ 546,483	$ 208,636
15	$ 71,878	$ 487,974					$ 559,852	$ 199,533
16	$ 74,035	$ 502,613	$ 3,116				$ 579,763	$ 192,895
17	$ 76,256	$ 517,691					$ 593,947	$ 184,479
18	$ 78,543	$ 533,222	$ 3,306				$ 615,071	$ 178,343
19	$ 80,900	$ 549,219					$ 630,118	$ 170,562
20	$ 83,327	$ 565,695	$ 3,507	$ 2,600,800	$ 1,265,121		$ 4,518,450	$ 1,141,769
21	$ 85,826	$ 582,666					$ 668,492	$ 157,694
22	$ 88,401	$ 600,146	$ 3,721				$ 692,268	$ 152,448
23	$ 91,053	$ 618,150					$ 709,204	$ 145,797
24	$ 93,785	$ 636,695	$ 3,947				$ 734,427	$ 140,947
25	$ 96,598	$ 655,796					$ 752,394	$ 134,797

Table 2B
Life Cycle Cost Analysis - Rehabilitation Option Two (continued)

				Periodic Costs				
Year	Routine Maintenance	Operating Cost	Inspection	Painting	Wearing Surface	Mechanical & Electrical	Annual Total	Present Value
26	$ 99,496	$ 675,470	$ 4,188				$ 779,153	$ 130,313
27	$ 102,481	$ 695,734					$ 798,215	$ 124,628
28	$ 105,556	$ 716,606	$ 4,443				$ 826,604	$ 120,482
29	$ 108,722	$ 738,104					$ 846,826	$ 115,225
30	$ 111,984	$ 760,247	$ 4,713		$ 67,640		$ 944,584	$ 119,984
31	$ 115,344	$ 783,054					$ 898,398	$ 106,532
32	$ 118,804	$ 806,546	$ 5,000				$ 930,350	$ 102,988
33	$ 122,368	$ 830,742					$ 953,110	$ 98,495
34	$ 126,039	$ 855,665	$ 5,305				$ 987,008	$ 95,219
35	$ 129,820	$ 881,335				$ 2,419,922	$ 3,431,076	$ 309,002
36	$ 133,715	$ 907,775	$ 5,628				$ 1,047,117	$ 88,035
37	$ 137,726	$ 935,008					$ 1,072,734	$ 84,194
38	$ 141,858	$ 963,058	$ 5,970				$ 1,110,886	$ 81,393
39	$ 146,114	$ 991,950					$ 1,138,063	$ 77,842
40	$ 150,497	$ 1,021,708	$ 6,334	$ 4,697,334	$ 2,284,949		$ 8,160,823	$ 521,088
41	$ 155,012	$ 1,052,359					$ 1,207,372	$ 71,969
42	$ 159,662	$ 1,083,930	$ 6,720				$ 1,250,312	$ 69,575
43	$ 164,452	$ 1,116,448					$ 1,280,900	$ 66,540
44	$ 169,386	$ 1,149,942	$ 7,129				$ 1,326,456	$ 64,326
45	$ 174,467	$ 1,184,440					$ 1,358,907	$ 61,520
46	$ 179,701	$ 1,219,973	$ 7,563				$ 1,407,238	$ 59,473
47	$ 185,092	$ 1,256,572					$ 1,441,665	$ 56,878
48	$ 190,645	$ 1,294,269	$ 8,024				$ 1,492,938	$ 54,986
49	$ 196,365	$ 1,333,098					$ 1,529,462	$ 52,587
50	$ 202,256	$ 1,373,090	$ 8,512		$ 122,165		$ 1,706,023	$ 54,759
51	$ 208,323	$ 1,414,283					$ 1,622,606	$ 48,620
52	$ 214,573	$ 1,456,712	$ 9,031				$ 1,680,315	$ 47,003
53	$ 221,010	$ 1,500,413					$ 1,721,423	$ 44,952
54	$ 227,640	$ 1,545,425	$ 9,581				$ 1,782,647	$ 43,457
55	$ 234,470	$ 1,591,788					$ 1,826,258	$ 41,561
56	$ 241,504	$ 1,639,542	$ 10,164				$ 1,891,210	$ 40,178
57	$ 248,749	$ 1,688,728					$ 1,937,477	$ 38,425
58	$ 256,211	$ 1,739,390	$ 10,783				$ 2,006,384	$ 37,147
59	$ 263,898	$ 1,791,572					$ 2,055,469	$ 35,526
60	$ 271,815	$ 1,845,319	$ 11,440	$ 8,483,908	$ 4,126,872		$ 14,739,353	$ 237,818
61	$ 279,969	$ 1,900,678					$ 2,180,647	$ 32,846
62	$ 288,368	$ 1,957,699	$ 12,137				$ 2,258,203	$ 31,753
63	$ 297,019	$ 2,016,430					$ 2,313,449	$ 30,368
64	$ 305,930	$ 2,076,922	$ 12,876				$ 2,395,728	$ 29,358
65	$ 315,108	$ 2,139,230					$ 2,454,338	$ 28,077
66	$ 324,561	$ 2,203,407	$ 13,660				$ 2,541,628	$ 27,143
67	$ 334,298	$ 2,269,509					$ 2,603,807	$ 25,959
68	$ 344,327	$ 2,337,595	$ 14,492				$ 2,696,413	$ 25,095
69	$ 354,656	$ 2,407,722					$ 2,762,379	$ 24,000
70	$ 365,296	$ 2,479,954	$ 15,374		$ 220,643	$ 6,809,327	$ 9,890,595	$ 80,220
						TOTAL COST:		**$ 71,854,000**